

AD-A188 817

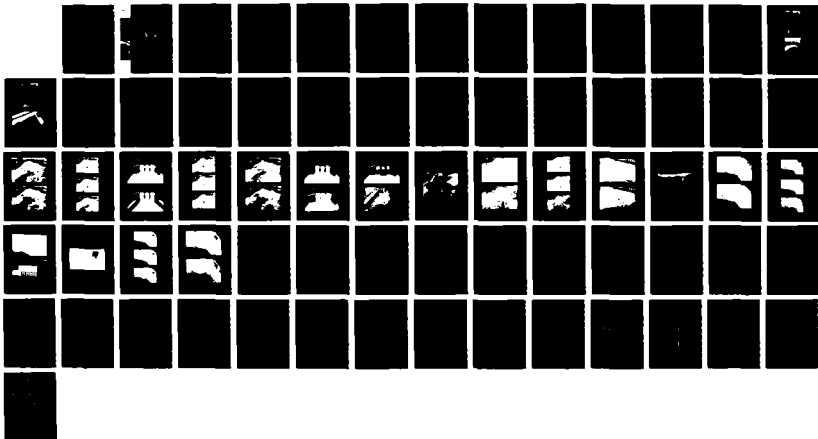
GALLIPOLIS LOCK INTAKE VORTEX STUDY OHIO RIVER
HYDRAULIC MODEL INVESTIGATION(U) ARMY ENGINEER
WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA.
R A DAVIDSON DEC 87 WES/TR/SL-87-17

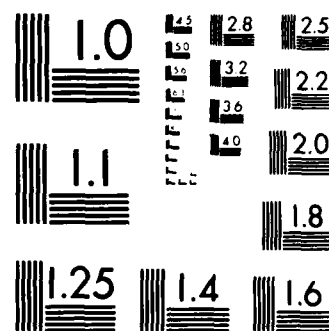
1/1

UNCLASSIFIED

F/G 13/2

NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



US Army Corps
of Engineers

TECHNICAL REPORT HL-87-17

4

GALLIPOLIS LOCK INTAKE VORTEX STUDY OHIO RIVER

DTIC FILE COPY

Hydraulic Model Investigation

by

Robert A. Davidson

Hydraulics Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

DTIC
ELECTE
FEB 10 1988
S D

AD-A188 817



December 1987

Final Report

Approved For Public Release, Distribution Unlimited

88 2 05 116

HYDRAULICS
LABORATORY

Prepared for US Army Engineer District, Huntington
Huntington, West Virginia 25701-2070

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

AD-A188817

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
1a. REPORT SECURITY CLASSIFICATION Unclassified		1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited		
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE				
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Technical Report HL-87-17		5. MONITORING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION USAEWES Hydraulics Laboratory	6b. OFFICE SYMBOL (if applicable) WESHS-L	7a. NAME OF MONITORING ORGANIZATION		
6c. ADDRESS (City, State, and ZIP Code) PO Box 631 Vicksburg, MS 39180-0631		7b. ADDRESS (City, State, and ZIP Code)		
8a. NAME OF FUNDING / SPONSORING ORGANIZATION USAED, Huntington	8b. OFFICE SYMBOL (if applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER		
8c. ADDRESS (City, State, and ZIP Code) 502 8th Street Huntington, WV 25701-2070		10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. PROJECT NO. TASK NO. WORK UNIT ACCESSION NO.		
11. TITLE (Include Security Classification) Gallipolis Lock Intake Vortex Study, Ohio River; Hydraulic Model Investigation				
12. PERSONAL AUTHOR(S) Davidson, Robert A.				
13a. TYPE OF REPORT Final report	13b. TIME COVERED FROM 1982 TO 1983	14. DATE OF REPORT (Year, Month, Day) December 1987	15. PAGE COUNT 69	
16. SUPPLEMENTARY NOTATION Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.				
17. COSATI CODES FIELD GROUP SUB-GROUP		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Gallipolis Lock Ohio River Hydraulic model Vortices Intake structures		
19. ABSTRACT (Continue on reverse if necessary and identify by block number) The existing Gallipolis Locks are located on the Ohio River at mile 279.2. Because of their location on an inside bend, the orientation for approach channels, velocity currents in the river, and the design of the approach walls, entry of downbound tows into the lock is hazardous and time consuming during periods of high flow. As a result of increasing traffic and tow sizes, these locks have become a serious problem to vessel movement along the Ohio River. Replacement locks will be constructed in the near future to alleviate these problems. Tests were conducted on a 1:25-scale model that reproduced 2,500 ft of the Ohio River beginning 188 ft upstream of the existing lock guide wall. Approximately 250 ft of the width of the river was reproduced. This model was used to evaluate the performance of the intake structures for the new locks. (Continued)				
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS		21. ABSTRACT SECURITY CLASSIFICATION Unclassified		
22a. NAME OF RESPONSIBLE INDIVIDUAL		22b. TELEPHONE (Include Area Code)		22c. OFFICE SYMBOL

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

19. ABSTRACT (Continued).

Two different alternate plans for the filling of the locks were tested. One plan consisted of filling the lock through long culverts extending from the river to the lock chamber. The other plan consisted of an intake canal extending from the river to the guide wall. Two intakes were located on the riverward side of the new lock approach wall, and one intake was located in the filling canal. Air-entraining vortices developed at the intake structure in both plans. The air-entraining vortices observed in both plans were eliminated by modification to the intake structure.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

PREFACE

The model investigation reported herein was authorized by the Office, Chief of Engineers (OCE), US Army, on 19 July 1982, at the request of US Army Engineer District, Huntington (ORH).

The study was conducted by personnel of the Hydraulics Laboratory, US Army Engineer Waterways Experiment Station (WES), during the period August 1982 to December 1983 under the direction of Messrs. H. B. Simmons and F. A. Herrmann, Jr., former and present Chiefs, Hydraulics Laboratory, and under the general supervision of Mr. J. L. Grace, Jr., Chief, Hydraulic Structures Division. Tests were conducted by Messrs. R. A. Davidson and T. E. Murphy, Jr., Locks and Conduits Branch, under the supervision of Mr. G. A. Pickering, Chief, Locks and Conduits Branch. This report was prepared by Mr. Davidson and edited by Mrs. Nancy Johnson, Information Technology Laboratory, under the Inter-Governmental Personnel Act.

Messrs. D. Armstrong and G. Drummond of the US Army Engineer Division, Ohio River, and C. Vandervelde, K. Crisp, K. Waddell, W. Barnes, and R. Spurlock, ORH, visited WES during the study to discuss test results and to correlate these results with concurrent design work.

COL Dwayne G. Lee, CE, is the Commander and Director of WES.
Dr. Robert W. Whalin is the Technical Director.

Accession For	
NTIS	<input checked="checked" type="checkbox"/>
DTIC	<input type="checkbox"/>
Unpublished	<input type="checkbox"/>
Justification	
By	
Date	
Signature	
Title	
A-1	

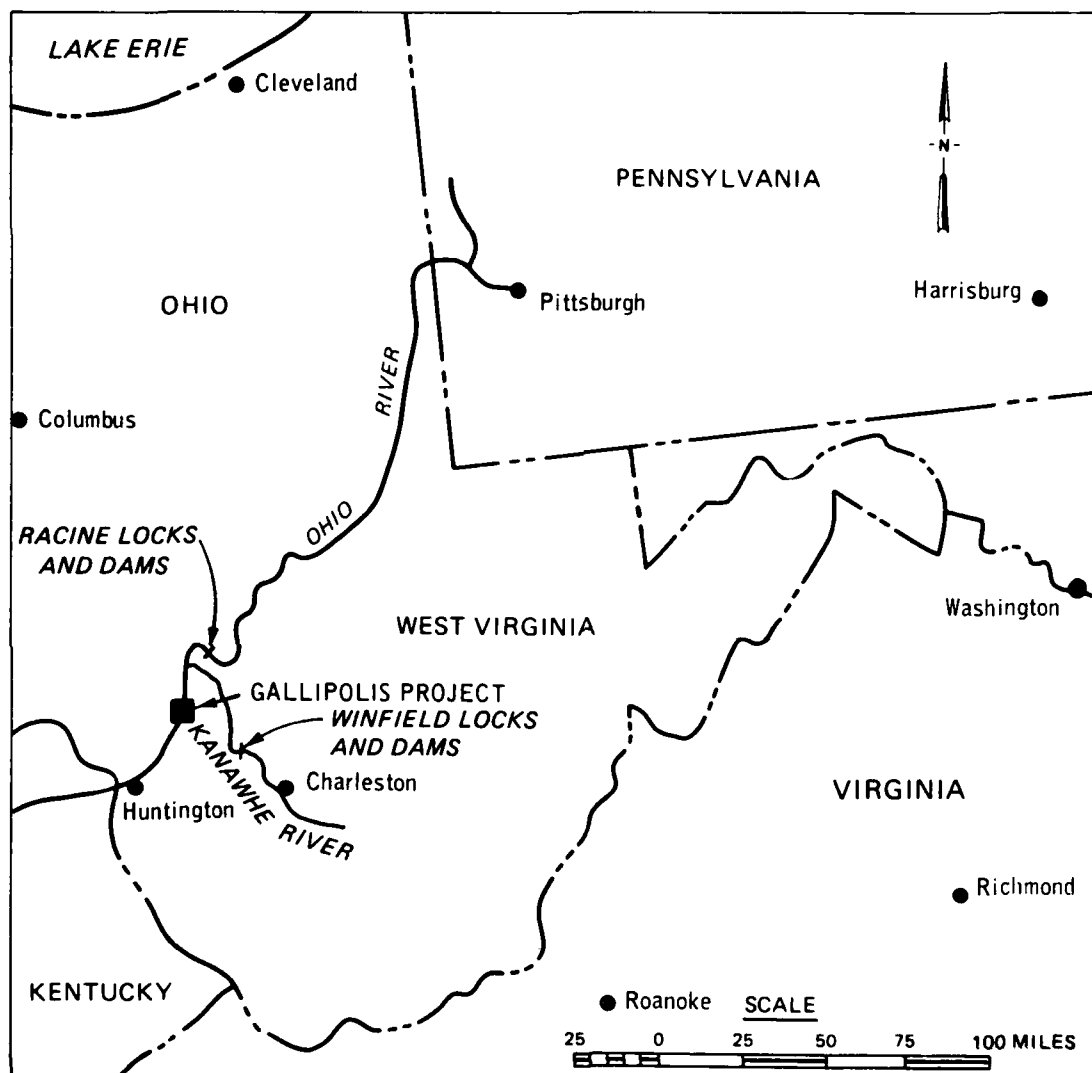
CONTENTS

	<u>Page</u>
PREFACE.....	1
CONVERSION FACTORS, NON-SI TO SI (METRIC)	
UNITS OF MEASUREMENT.....	3
PART I: INTRODUCTION.....	5
Project Description.....	5
Purpose of Model Investigation.....	7
PART II: MODEL.....	8
Description.....	8
Model Appurtenances.....	8
Scale Relations.....	11
PART III: TESTS AND RESULTS.....	12
Alternative I Filling Scheme.....	12
Alternative II Filling Scheme.....	14
PART IV: DISCUSSION OF RESULTS AND CONCLUSION.....	16
TABLES 1-2	
PHOTOS 1-18	
PLATES 1-24	

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI
(metric) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
cubic feet	0.02831685	cubic metres
degrees (angle)	0.01745329	radians
feet	0.3048	metres
inches	2.54	centimetres
miles (US statute)	1.609344	kilometres



LOCATION MAP

Figure 1. Location map

GALLIPOLIS LOCK INTAKE VORTEX STUDY

OHIO RIVER

Hydraulic Model Investigation

PART I: INTRODUCTION

Project Description

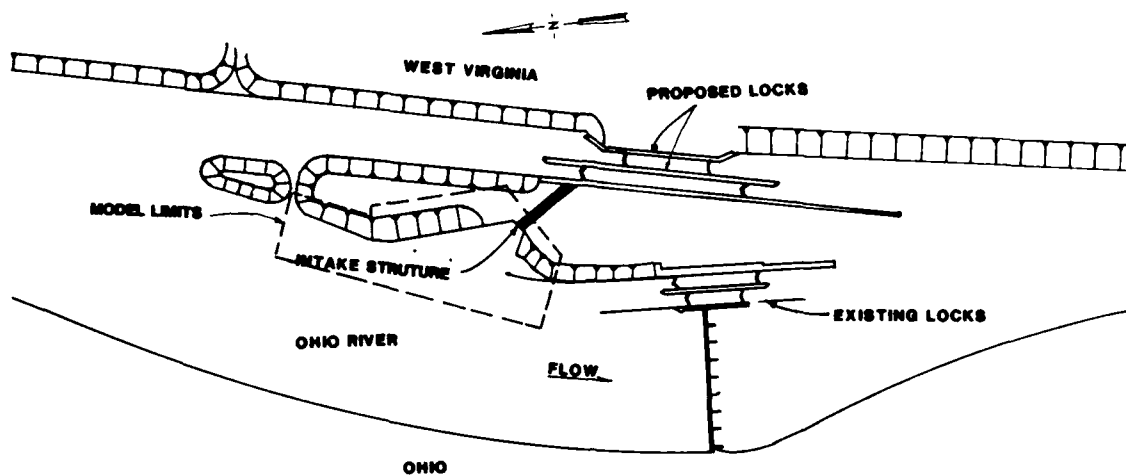
1. The Gallipolis Locks and Dam, constructed in 1937, are located in the Middle Ohio Valley at Ohio River mile 279.2, about 14 miles* downstream from the mouth of the Kanawha River (Figure 1). The navigation pool extends 41.7 miles up the Ohio River to Racine Lock and Dam and 31.1 miles up the Kanawha River to Winfield Locks and Dam. The normal pool elevation is 538.** The Gallipolis Dam is a high-lift, nonnavigable gated structure. Because of the location of the locks on an inside bend, the orientation for approach channels, velocity currents in the river, and the design of the approach walls, entry of downbound tows into the lock is hazardous and time consuming during periods of high flow. As a result of increasing traffic and tow sizes, these locks have become a serious problem to vessel movement on the Ohio River. Replacement locks will be constructed in the near future to alleviate these problems. The proposed replacement locks are to be located in a canal on the West Virginia side of the river directly east of the existing lock (Figure 2). The flow from Flatfoot Creek that presently empties into the Ohio River downstream from the existing locks on the West Virginia side will be directed into a new channel upstream from the replacement locks.

2. Two alternatives for filling the locks were considered. Alternative I (Figure 2a) consisted of filling the locks from an intake structure located on the river side of the island. The structure would contain three intake passages for filling the main lock and an auxiliary lock. A single barrel entrance would be provided for each intake culvert.

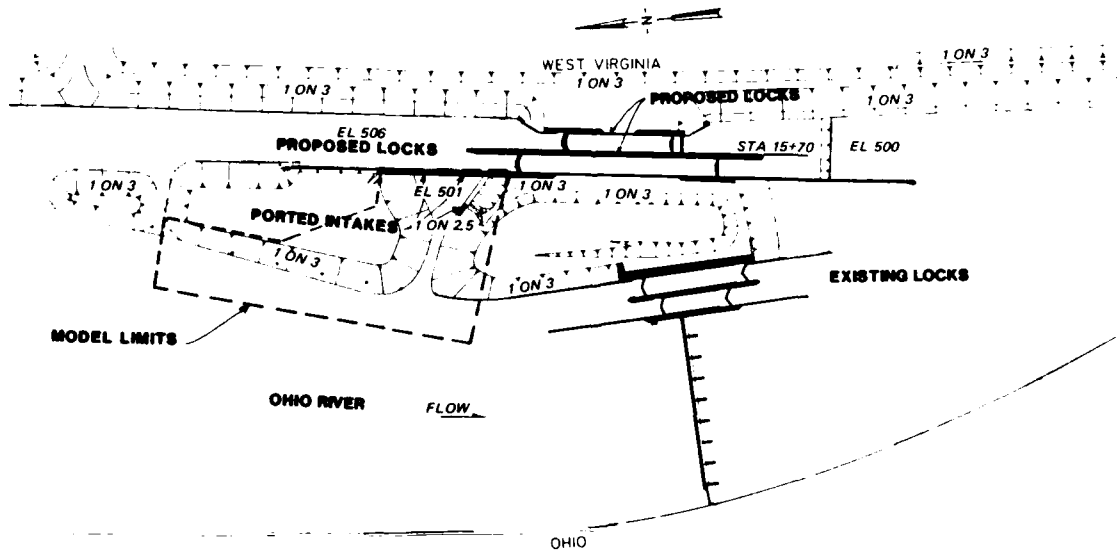
3. Alternative II (Figure 2b) consisted of an intake canal extending

* A table of factors for converting non-SI units of measurements to SI (metric) units is presented on page 3.

** All elevations (el) cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD).



a. Alternative I filling scheme



b. Alternative II filling scheme

Figure 2. Alternative filling schemes

from the river to the proposed guide wall. Two filling culverts would have ported intakes located on the riverward face of the proposed lock guide wall, and one filling culvert would have a ported intake located in the filling canal.

Purpose of Model Investigation

4. A model was considered necessary to determine whether or not vortex formation would be a problem in either of the alternate filling schemes.

PART II: THE MODEL

Description

5. The model, constructed to a scale of 1:25, reproduced approximately 2,500 ft of the Ohio River beginning 1,800 ft upstream of the existing lock guide wall (Figure 3a). Approximately 250 ft of the width of the river was reproduced. Portions of the model representing upstream topography, approach, exit, and overbank areas were modeled of cement mortar to sheet metal templates and were given a brushed finish.

6. Two different alternatives for filling the locks were tested. The alternative I filling scheme consisted of filling the locks from the river through long culverts. Approximately 310 ft of culvert was reproduced. The intake structure and culverts (Figure 3b, Plate 1) were constructed of plastic.

7. The alternative II filling scheme consisted of filling the locks from a ditch (Figure 4a). Two intakes were located on the riverward side of the new lock approach wall, and one intake was located in the filling ditch (Figure 4b). The intakes were constructed of plastic and sheet metal, and the conduits were constructed of plastic. The intake tower and the new lock approach wall were constructed with plastic-coated plywood.

Model Appurtenances

8. Water was supplied to the model through a circulating system. The headbay and tailbay of the model contained a skimming weir that maintained essentially a constant upper pool during filling operations. The filling curves of the locks were reproduced by placing computer-controlled actuators at the end of each conduit. Dye and confetti were used to study subsurface and surface current directions in the approach, particularly in the vicinity of the problem near the intakes. Steel rails, set to grade along both sides of the model, provided a reference plane for measuring devices. Velocities were measured with a current and kent meter.

9. Discharges through the model were controlled by means of venturi and orifice meters. Certain flow conditions in the model were recorded photographically.



a. General view

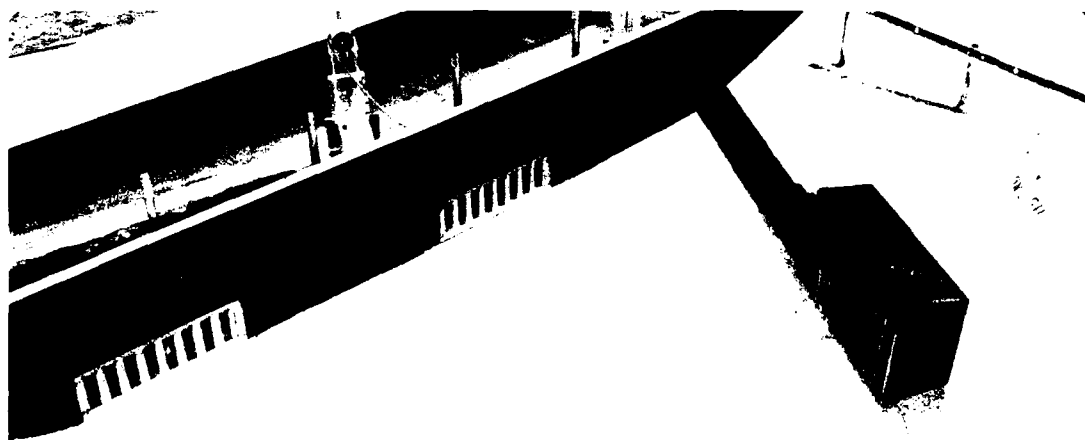


b. Type 1 design intake

Figure 3. Alternative I filling scheme: dry bed



a. General view



b. Intake locations

Figure 4. Alternative II filling scheme: dry bed

Scale Relations

10. The accepted equations of hydraulic similitude, based on Froudian relations, were used to express mathematical relations between the dimensions and hydraulic quantities of the model and prototype. General relations for transference of model data to prototype equivalent are presented in the following tabulation:

<u>Dimension*</u>	<u>Ratio</u>	<u>Model to Prototype Scale Relation</u>
Length	$L_r = L$	1:25
Area	$A_r = L_r^2$	1:625
Time	$T_r = L_r^{1/2}$	1:5
Velocity	$V_r = L_r^{1/2}$	1:5
Discharge	$Q_r = L_r^{5/2}$	1:3,125

* Dimensions are in terms of length.

PART III: TESTS AND RESULTS

11. Tests were conducted to determine if any air-entraining vortices would form at the entrance to the intake structure during a filling operation. The hydrographs for filling the locks were furnished by the Huntington District and are shown in Plates 2 and 3. Also, if a vortex was found, modifications were made to alleviate the problem. Two alternate filling schemes were tested.

Alternative I Filling Scheme

12. The alternative I filling scheme consisted of filling the locks from the river through long culverts. The intake structure contained three passages for filling the main lock and an auxiliary lock (Figure 2). Several different designs were tested in an effort to relieve the vortex problem. A description and the results of each test are given in Table 1.

Type 1 design intake

13. Flow conditions with both a 2- and a 4-min valve time were observed and found to be unsatisfactory. Approach flow was found to be unsymmetrical, and this caused the majority of flow to concentrate along the side of the approach area. Flow conditions were documented photographically and are shown in Photo 1. Also the intake approach walls did not begin at the intake structure's abutments, which caused severe vortices to form at the intake structure (Photo 2). Velocities measured in the approach are shown in Plates 4-6.

Alternate wall design

14. Tests of different approach wall positions were conducted in an effort to reduce the severity of the vortices at the entrance to the intake structure. The wall alignment, designated as the No. 2 wall in Plate 7, was found to be the best design. This wall reduced the severity of the vortices (Photo 3) and improved the approach conditions (Photo 4). However, the vortices were still present.

Alternate intake designs

15. Various modifications to the intake structure were tested in an effort to reduce or eliminate the vortices. These tests were conducted with both the No. 1 and 2 wing walls in place as described in Table 1.

16. Tests were conducted with gridded bar racks having 1- by 2-ft

openings positioned in the proposed stop log recesses. This design, designated as type 2 design intake (Plate 8), eliminated the air-entraining vortices (Photo 5), but the small grid openings would require periodic cleaning. Thus, this design was not considered feasible.

17. Extensions 10 ft long placed on the center piers, type 3 design intake (Plate 9), did not decrease the intensity of the vortices (Photo 6).

18. Vortex suppressor plates were installed at the same elevation as the roof of the conduit and were extended upstream over the full length of the intake piers, type 4 design intake (Plate 9). This design eliminated air-entraining vortices (Photo 7) but did not provide access for cleaning the trashracks; therefore, the type 4 design intake was not considered to be a feasible solution.

19. Tests conducted with types 5, 6, and 7 design intakes (Plates 10 and 11) indicated little improvement in eliminating air-entraining vortices during filling operations.

Recommended design

20. Vortex suppressors were installed at the same elevation as the roof of the conduit and were extended upstream 17 ft along the length of the intake piers. The vortex suppressor had a thickness of 15.4 ft. This design, designated type 8 design intake (Plates 11 and 12, Photo 8), eliminated the vortex.

21. The invert of the approach channel from the intake to 50 ft upstream was graded to el 490 and then extended upstream on a 1V on 3H slope to el 501 (Plate 13). Approach wing walls were installed in position No. 2 at a 30-deg angle. A dike was placed between the old lock approach wall and the mooring pier immediately upstream of the old lock approach wall (Photo 9, Plate 13). Flow conditions were documented photographically and are shown in Photo 10. Without this dike in place, small vortices occurred during some runs (Table 1). But with this dike in place, the air-entraining vortices were completely eliminated during filling operations. Velocities measured in the approach area are shown in Plates 14-16.

Log boom

22. Log booms constructed of 1- by 2- by 20-ft timbers were tested in the approach area to the intake structure (Photo 11) to determine if ice could be kept from entering the approach area to the intake structure during a filling operation. Simulated ice was placed upstream of the log booms and allowed to flow downstream during a fill operation (Photo 12).

23. The ratios of cable length to chord length (straight-line distance from one end of cable to another) used in successful boom designs have varied from 1.06 to 1.25. A cable to chord ratio of 1.15 was tested and found to be 95 percent effective in keeping ice out of the approach area during a filling operation. A cable to chord ratio of 1.06 was also tested and found to be 99 percent effective in keeping ice from entering the approach area to the intake structure during a fill operation.

Alternative II Filling Scheme

Original design (type 1 design approach wall)

24. The alternative II filling scheme involved filling the main and auxiliary locks from the river through a ditch (Figure 2, Plate 17). The location of the three intake structures is shown in Photo 13. Flow conditions were observed near the intake during the filling of both the main and auxiliary locks simultaneously. The 4-min valve opening time caused a more severe condition in the model than the 2-min valve time. Therefore, all tests were conducted with a 4-min valve opening time. An upper pool or river stage of 538.0 was maintained during the tests. Flow conditions were documented photographically and are shown in Photo 14. Velocities measured in the ditch are shown in Plate 18.

25. With the 4-min valve opening time, air-entraining vortices formed at the intake tower (Photo 15). No vortices formed at either of the wall intakes.

Alternate designs

26. Several different approach wall shapes, lengths, and positions (Plates 19-22) were tested in an attempt to alleviate vortex formation at the intake tower. Results of tests with various designs are described in Table 2. As shown in from this table, some of the modifications were successful in eliminating air-entraining vortices while others were not.

Recommended design

27. The type 11 design approach wall (Plate 19) was considered the best design of all the approach walls tested. This design included a quarter of an ellipse with a major axis of 90 ft and a minor axis of 46 ft placed immediately upstream from the intake tower (Photo 16). No air-entraining

vortex formed during any part of the filling operation (Photo 17). The trash-rack guides caused a slight disturbance of flow near the face of the intake tower, but this was not considered objectionable and did not cause an air-entraining vortex to form. A layout of the recommended alternative II filling scheme is shown in Plate 23. Photographic documentation of flow conditions in the ditch using the type II design approach wall during a filling operation can be seen in Photo 18. Velocities obtained in the ditch are shown in Plate 24.

PART IV: DISCUSSION OF RESULTS AND CONCLUSION

28. Model tests were conducted to determine if there would be a problem of vortex formation at the intakes of the proposed locks. Observations of flow conditions with both alternative I and alternative II filling schemes showed that a vortex problem would exist in either of the alternate filling schemes as originally designed.

29. In testing of the alternative I filling scheme, it was observed that several factors contributed to the formation of severe air-entraining vortices:

- a. The flow entering the intake structure was unsymmetrical.
- b. The intake approach walls did not begin at the intake abutments, thereby causing water to swirl around the abutments.
- c. There was not enough submergence for this intake design.

30. As a result of the testing of several intake designs and different approach wall positions, a design that eliminated all air-entraining vortices was developed. The invert of the intake was lowered from el 505 to el 490. The invert of the approach channel from the intake to 50 ft upstream was graded to el 490 and then extended upstream on a 1V on 3H slope to el 501. A 15.4-ft-thick vortex suppressor was placed at the same elevation as the roof of the conduit and was extended 17 ft upstream along the intake piers. The flow entering the structure was made more symmetrical by starting the intake approach walls at the intake abutments and by placing a dike upstream of the existing lock guide wall.

31. In testing of the alternative II filling scheme, it was observed that during a filling operation the water swirled around the sharp corner of the upstream front face of the intake tower, causing a severe air-entraining vortex to set up during most of the fill.

32. As the result of testing several different approach walls, in an attempt to streamline flow along the face of the intake tower, a design that eliminated all air-entraining vortices was developed. This design included a straight vertical wall and a quarter of an ellipse with a major axis of 90 ft and a minor axis of 46 ft immediately upstream of the intake tower.

Table 1

Alternative I Filling Scheme

Results of Intake Designs Tested, 2- and 4-Min Valve Speed

Pool el 538.0

Test No.	Intake Design (See Plate 1)	Wing Wall Angle, deg		Cofferdam Cells 1-8*	Invert Elevation of Intake	Comments
		Position No. 1* θ_1	Position No. 2* θ_2			
1	Type 1 (See Plate 1)	30		Out	505.0	Severe air-entraining vortices occurred almost the entire length of each test run.
2	Type 1	30		Out	501.0	Severe air-entraining vortices occurred almost the entire length of each test run.
3	Type 1	30		Out	495.0	Large air-entraining vortices occurred during most of the length of each test run.
4	Type 1		36	Out	505.0	Large air-entraining vortices occurred almost the entire length of each test run.
5	Type 1		36	Out	501.0	Large air-entraining vortices occurred 50 percent of the time during each test run.

(Continued)

* See Plate 7

(Sheet 1 of 5)

Table 1 (Continued)

Test No.	Intake Design	Wing Wall Angle, deg		Cofferdam Cells 1-8	Invert Elevation of Intake	Comments
		Position No. 1 θ_1	Position No. 2 θ_2			
6	Type 1		36	Out	495.0	Small air-entraining vortices occurred 30 percent of the time during each test run.
7	Type 1		36 600-ft Radius circular wall	In	495.0	Small air-entraining vortices occurred during 7 percent of the test runs.
8	Type 1		36 600-ft Radius circular wall	In	501.0	Small air-entraining vortices occurred during 25 percent of the test runs.
9	Type 1		36 600-ft Radius circular wall	Out	495.0	Small air-entraining vortices occurred during 10 percent of the test runs.
10	Type 2 (See Plate 8)	30		Out	505.0	Small air-entraining vortices occurred 30 percent of the time during each test run.
11	Type 2		36	Out	505.0	No air was entrained during any test run.
12	Type 3 (See Plate 9)	30		Out	505.0	Severe air-entraining vortices occurred almost the entire length of each test run.

(Continued)

(Sheet 2 of 5)

Table 1 (Continued)

Test No.	Intake Design	Wing Wall Angle, deg		Cofferdam Cells 1-8	Invert Elevation of Intake	Comments
		Position No. 1 θ_1	Position No. 2 θ_2			
13	Type 4 (See Plate 9)		36	Out	505.0	No air was entrained during any test run.
14	Type 5 (See Plate 10)	30		Out	505.0	Small air-entraining vortices occurred during each test run.
15	Type 5	30		Out	501.0	Small air-entraining vortices occurred during each test run.
16	Type 6 (See Plate 10)	30		Out	505.0	Small air-entraining vortices occurred during each test run.
17	Type 6		36	Out	505.0	Small air-entraining vortices occurred during 85 percent of the test runs.
18	Type 6		36	Out	501.0	Small air-entraining vortices occurred in 85 percent of the test runs.
19	Type 6		36	Out	495.0	Small air-entraining vortices occurred in 7 percent of the test runs.

(Continued)

(Sheet 3 of 5)

Table 1 (Continued)

Test No.	Intake Design	Wing Wall Angle, deg		Cofferdam Cells 1-8	Invert Elevation of Intake	Comments
		Position No. 1 θ_1	Position No. 2 θ_2			
20	Type 6		36	In	495.0	Small air-entraining vortices occurred in 7 percent of the test runs.
21	Type 6		36	Out	495.0	Small air-entraining vortices occurred in 50 percent of the test runs.
22	Type 6		13	In	505.0	Small air-entraining vortices occurred in 50 percent of the test runs.
23	Type 6		0	In	505.0	Small air-entraining vortices occurred in 50 percent of the test runs.
24	Type 6		30	In	505.0	Small air-entraining vortices occurred in 50 percent of the test runs.
25	Type 6		30	Out	495.0	Small air-entraining vortices occurred in 50 percent of the test runs.
26	Type 6		30	In	490.0	Small air-entraining vortices occurred in 7 percent of the test runs.

(Continued)

(Sheet 4 of 5)

Table 1 (Concluded)

Test No.	Intake Design	Wing Wall Angle, deg		Cofferdam Cells 1-8	Invert Elevation of Intake	Comments
		Position No. 1 θ_1	Position No. 2 θ_2			
27	Type 6		30	Out	490.0	Small air-entraining vortices occurred in 20 percent of the test runs.
28	Type 7 (See Plate 11)		30	In	505.0	Small air-entraining vortices occurred in 50 percent of the test runs.
29	Type 7		30	In	501.0	Small air-entraining vortices occurred in 10 percent of the test runs.
30	Type 7		30	In	495.0	Small air-entraining vortices occurred in 90 percent of the test runs.
31	Type 7		30	In	490.0	Small air-entraining vortices occurred in 90 percent of the test runs.
32	Type 8 (See Plate 12)		30	Out	490.0	Small air-entraining vortices occurred in 10 percent of the test runs.
33	Type 8 (Recommended)		30	In	490.0	No air-entraining vortices developed in any test run.

Table 2

Alternative II Filling Scheme

Results of Approach Wall Designs Tested, 4-Min Valve Speed

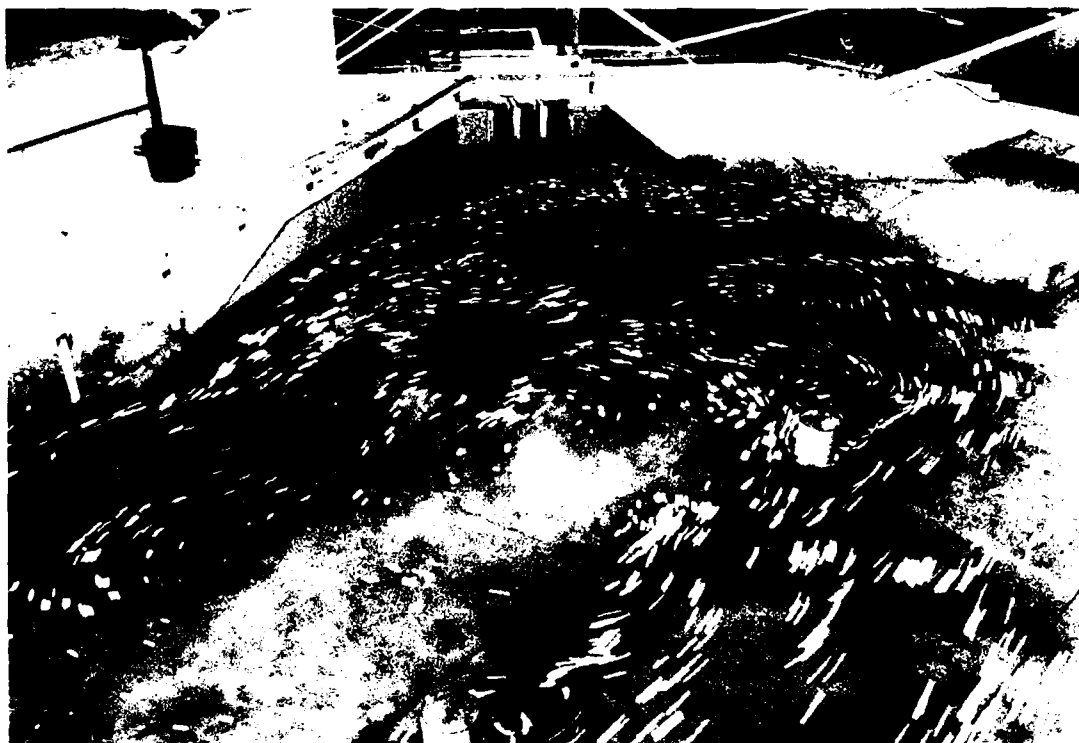
Pool el 538.0

Approach Wall Design	Description	Type of Wall	Comments
Type 1	No approach wall. Original design.	None	A large vortex occurred 80 percent of the time during each run.
Type 2	A quarter-circle wall with a 30-ft radius was placed immediately upstream of the intake tower.	Free standing	Small air-entraining vortex formed several times during 30 percent of the test runs.
Type 3	A 50-ft straight wall was placed immediately upstream of the intake tower.	Free standing	Small air-entraining vortex formed several times during 30 percent of the test runs.
Type 4	A 50-ft straight wall was placed in series immediately upstream of the intake tower.	Free standing	Small vortices occurred during each test run; but none were air entraining.
Type 5	A quarter of an ellipse with a major axis of 90 ft and a minor axis of 60 ft was placed immediately upstream of the intake tower.	Free standing	Small air-entraining vortex formed in 15 percent of the test runs.
Type 6	A 10-ft straight wall and a quarter of an ellipse with a major axis of 90 ft and a minor axis of 60 ft were placed immediately upstream of the intake tower.	Free standing	Small air-entraining vortex formed in 15 percent of the test runs.

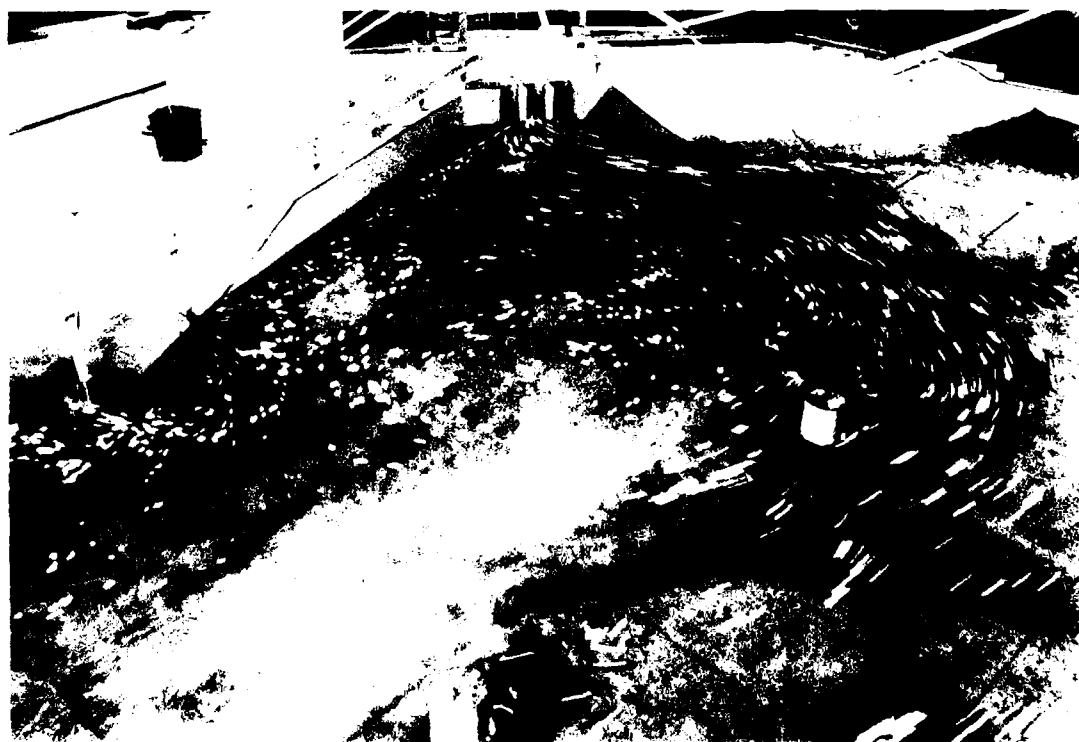
(Continued)

Table 2 (Concluded)

Approach Wall Design	Description	Type of Wall	Comments
Type 7	A 15-ft straight wall and a quarter of an ellipse with a major axis of 40 ft and a minor axis of 30 ft were placed immediately upstream of the intake tower.	Free standing	Small air-entraining vortex formed in 15 percent of the test runs.
Type 8	A 25-ft straight wall and a quarter of an ellipse with a major axis of 50 ft and a minor axis of 30 ft were placed in series immediately upstream of the intake tower.	Free standing	Small air vortex formed in 15 percent of the test runs.
Type 9	A 25-ft straight wall and a quarter of an ellipse with a major axis of 40 ft and a minor axis of 30 ft were placed immediately upstream of the intake tower.	Full	Small dimple vortices were observed. No air-entraining vortices formed in any of the test runs.
Type 10	A quarter of an ellipse with a major axis of 90 ft and a minor axis of 60 ft was placed immediately upstream of the intake tower.	Full	Small dimple vortices were observed. No air-entraining vortices formed in any of the test runs.
Type 11	A quarter of an ellipse with a major axis of 90 ft and a minor axis of 46 ft was placed immediately upstream of the intake tower. A 2-ft wall was placed tangent to this wall; then a 5-ft quarter-circular wall was placed on this short wall. The wall was tied back to the intake tower with a 40-ft straight wall.	Full	No air-entraining vortex was seen in any of the test runs.



a. Before filling started

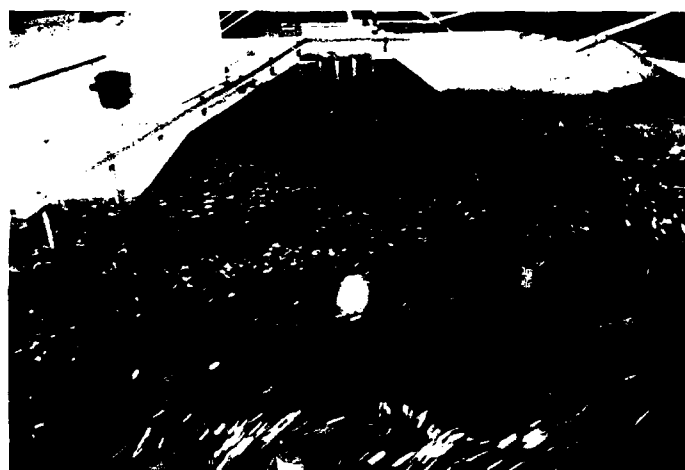


b. 2.0 min after filling started

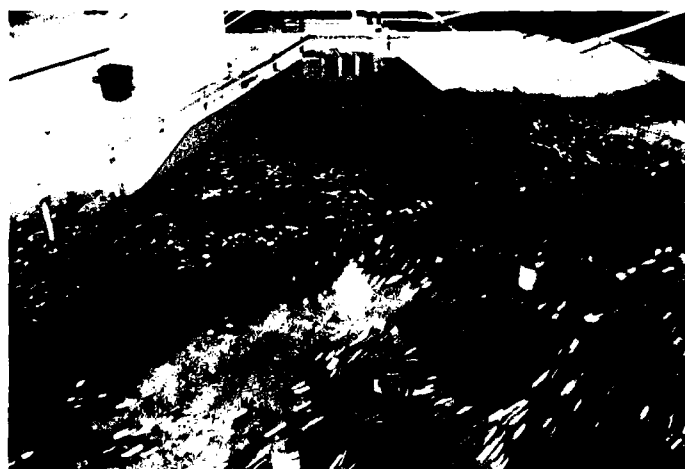
Photo 1. Surface currents during filling operation; type 1 design intake, time exposure 5 sec, upper pool el 538.0 (Continued)



c. 4.0 min after filling started



d. 6.0 min after filling started



e. 8.0 min after filling started

Photo 1. (Concluded)

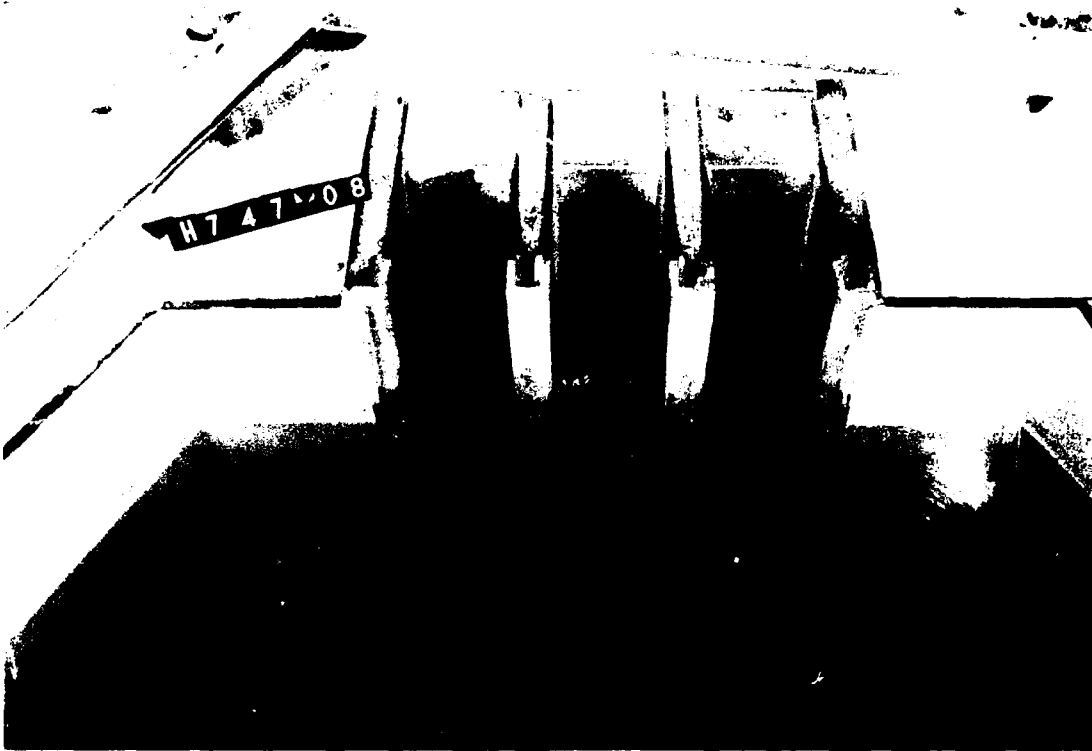


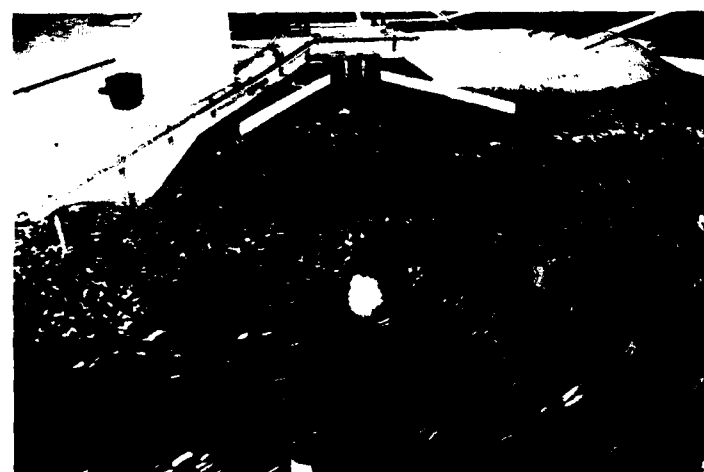
Photo 2. Type 1 design intake



Photo 3. Type 2 design approach walls



a. Before filling started

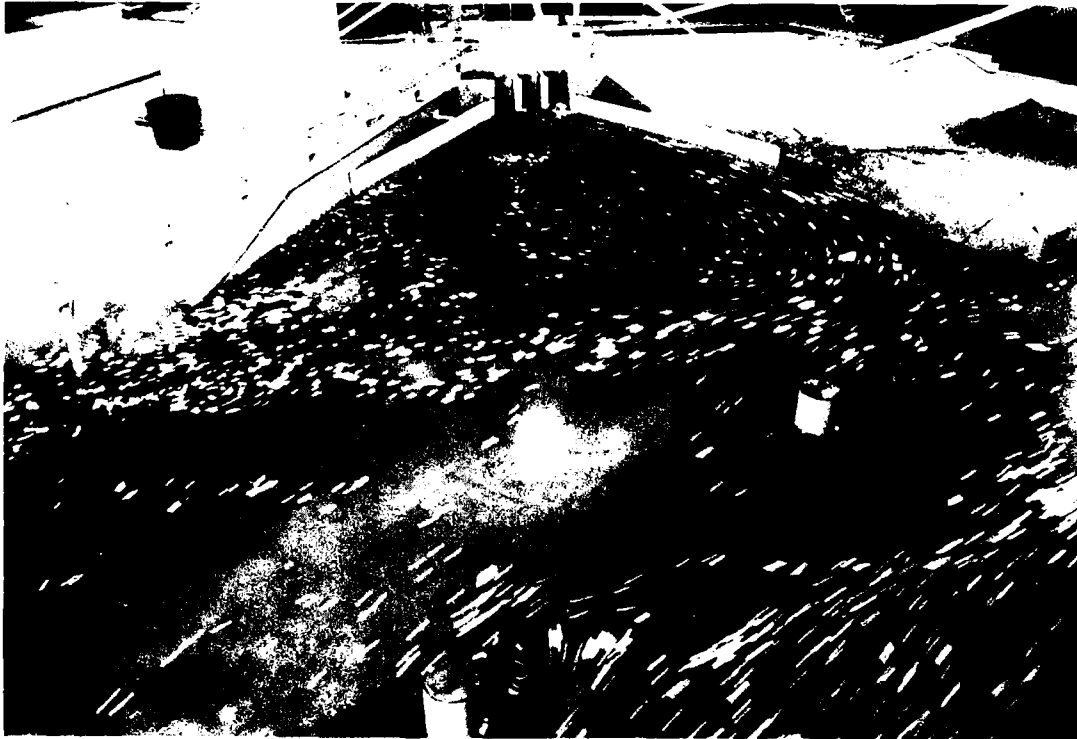


b. 2.0 min after filling started



c. 4.0 min after filling started

Photo 4. Surface currents during filling operation; type 1 design intake structure, wall position No. 2, time exposure 5 sec, upper pool el 538.0 (Continued)



d. 6.0 min after filling started



e. 8.0 min after filling started

Photo 4. (Concluded)

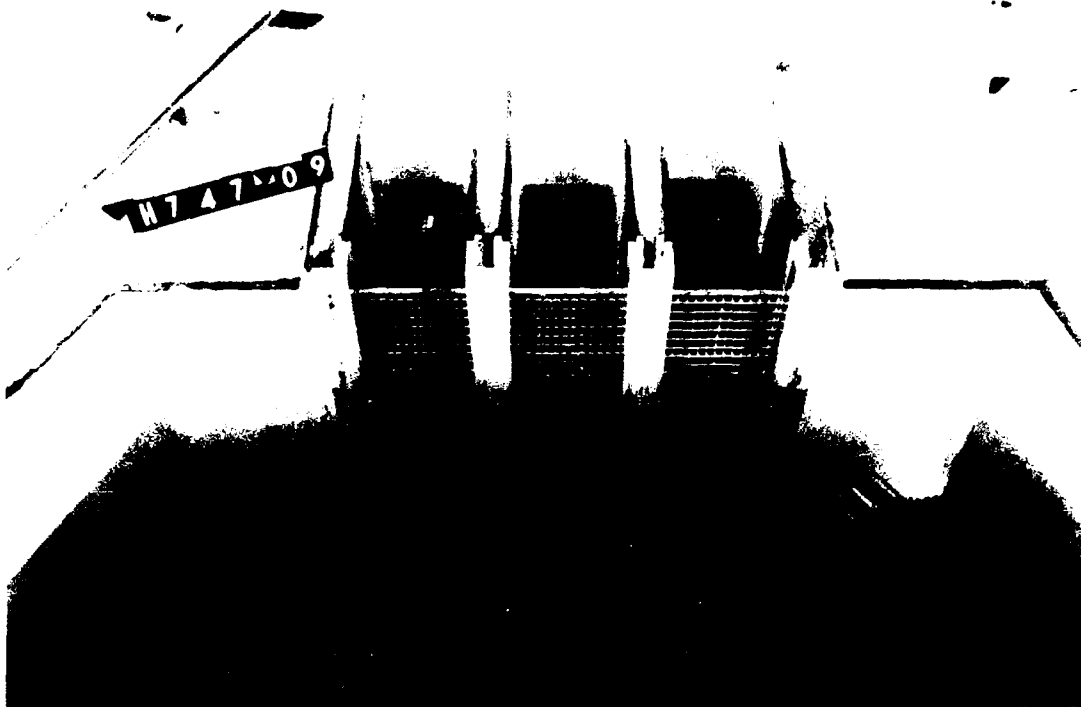


Photo 5. Type 2 design intake

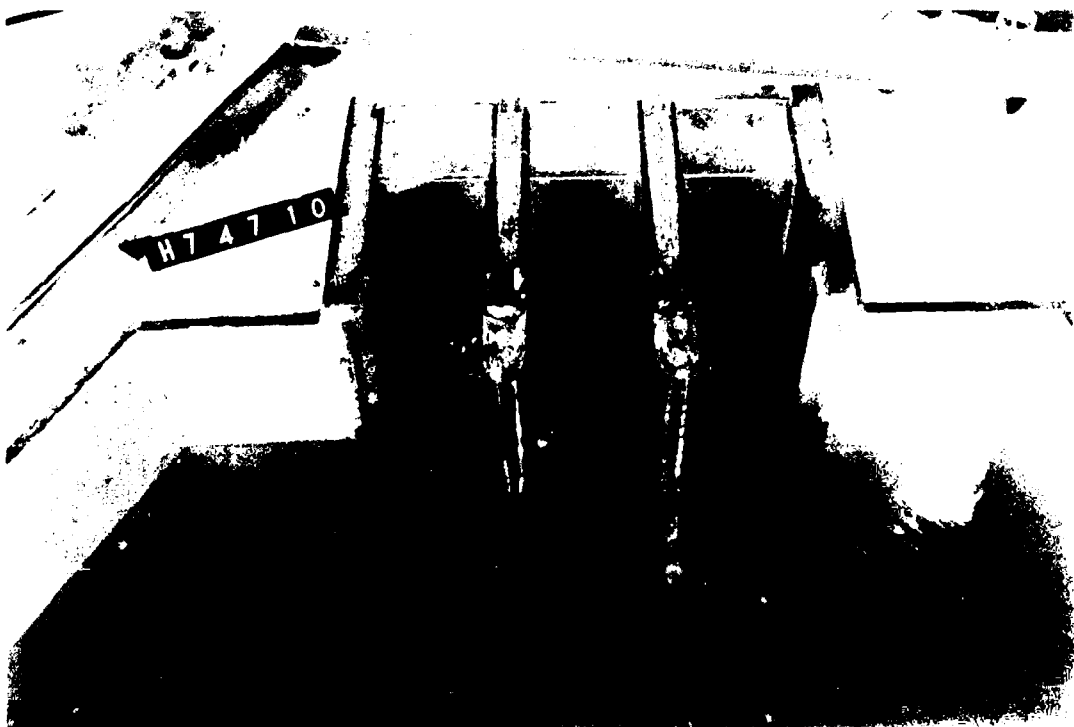


Photo 6. Type 3 design intake



Photo 7. Type 4 design intake

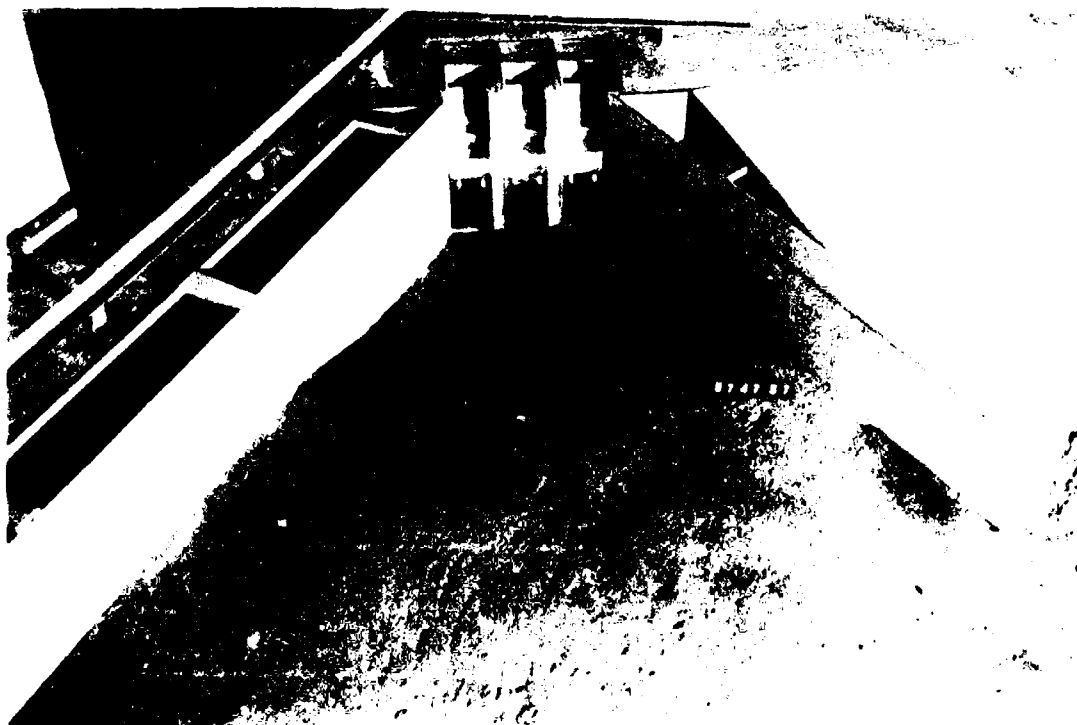
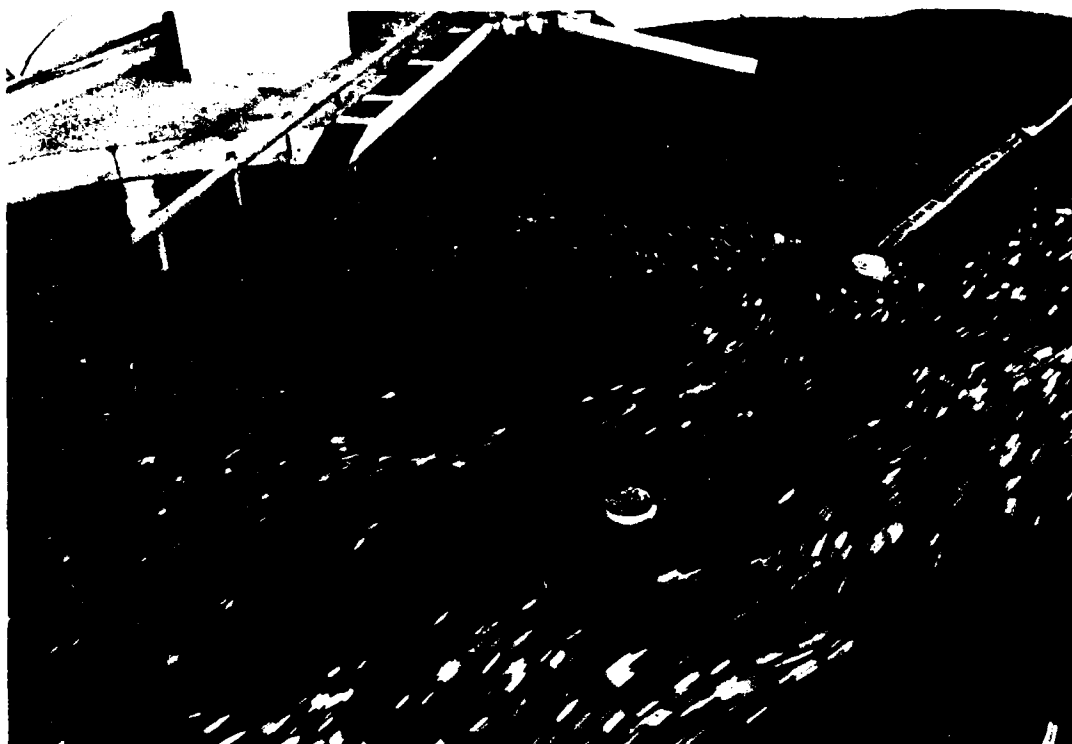


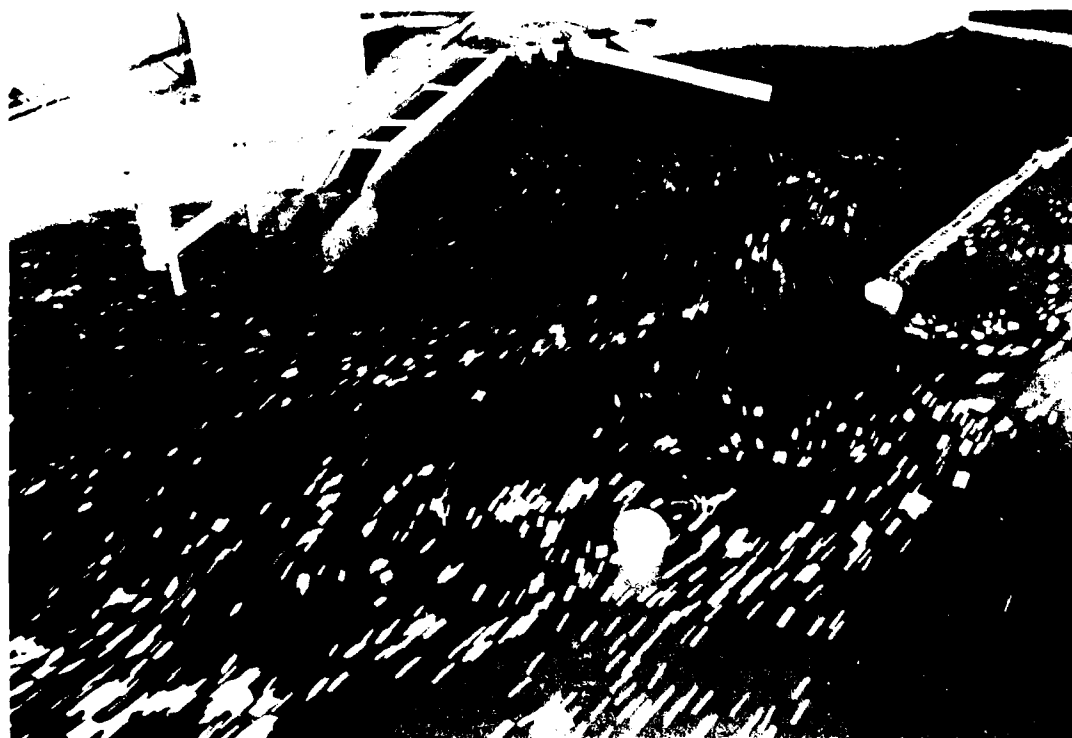
Photo 8. Type 8 design intake



Photo 9. Alternative I filling scheme (recommended design)

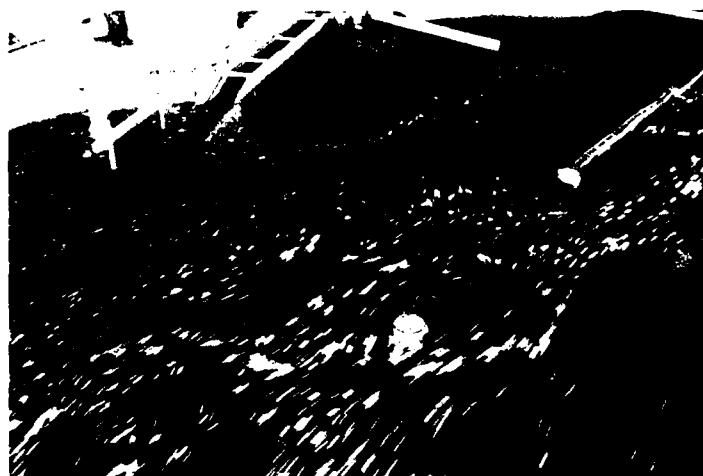


a. Before filling started

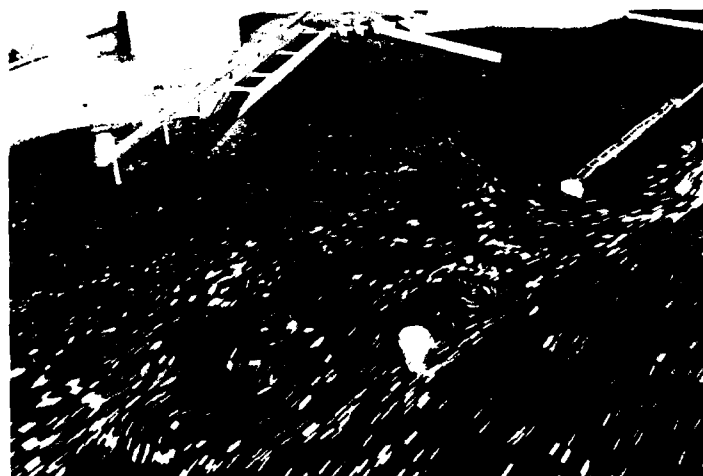


b. 2.0 min after filling started

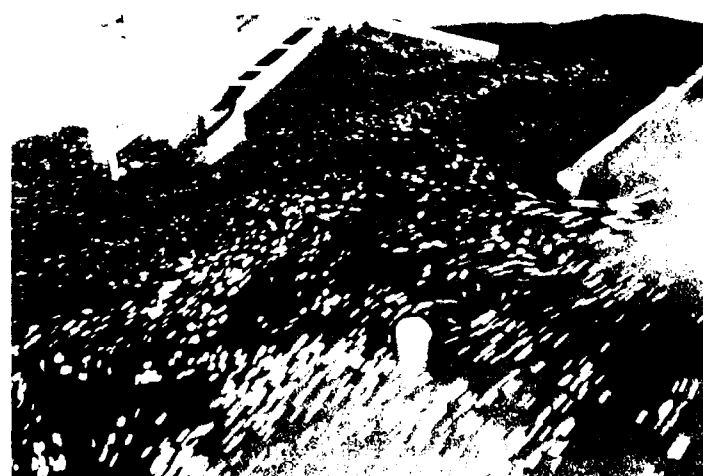
Photo 10. Surface currents during filling operation; type 8
(recommended) design intake, time exposure 5 sec, upper pool
el 538.0 (Continued)



c. 4.0 min after filling started



d. 6.0 min after filling started



e. 8.0 min after filling started

Photo 10 (Concluded)

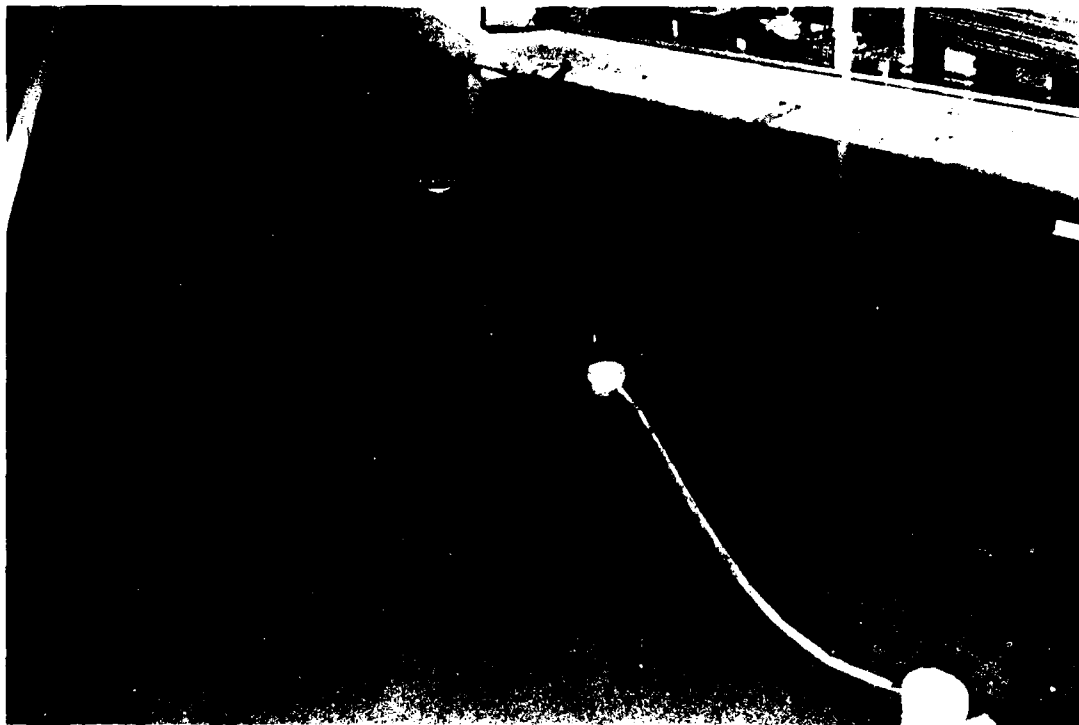


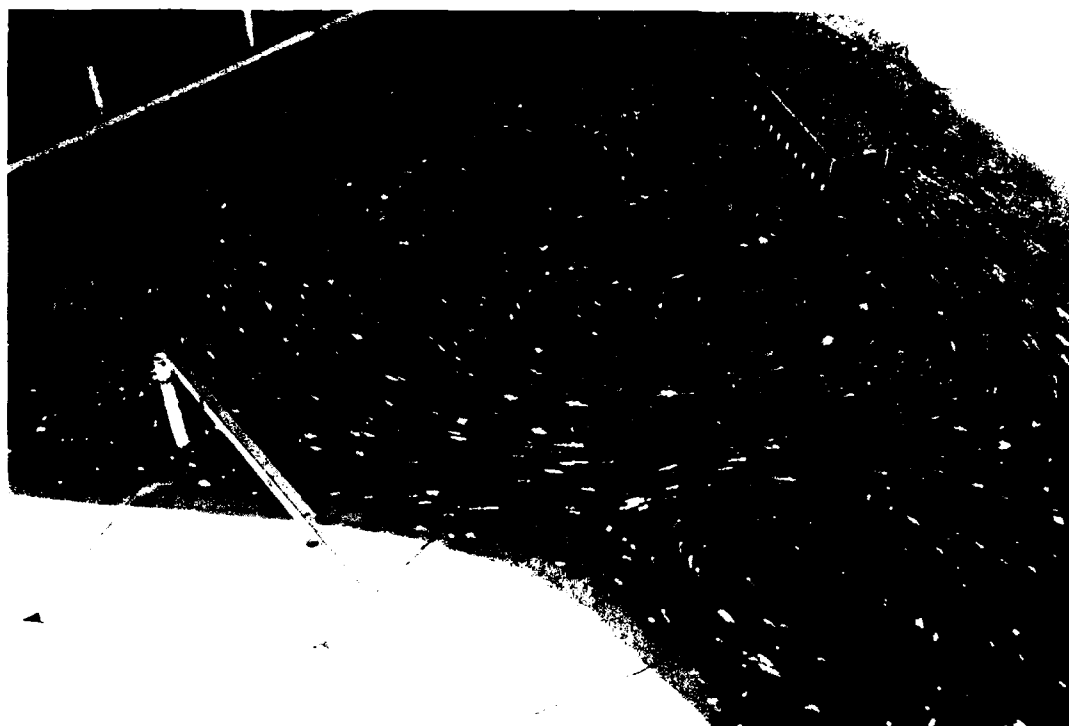
Photo 11. Log boom



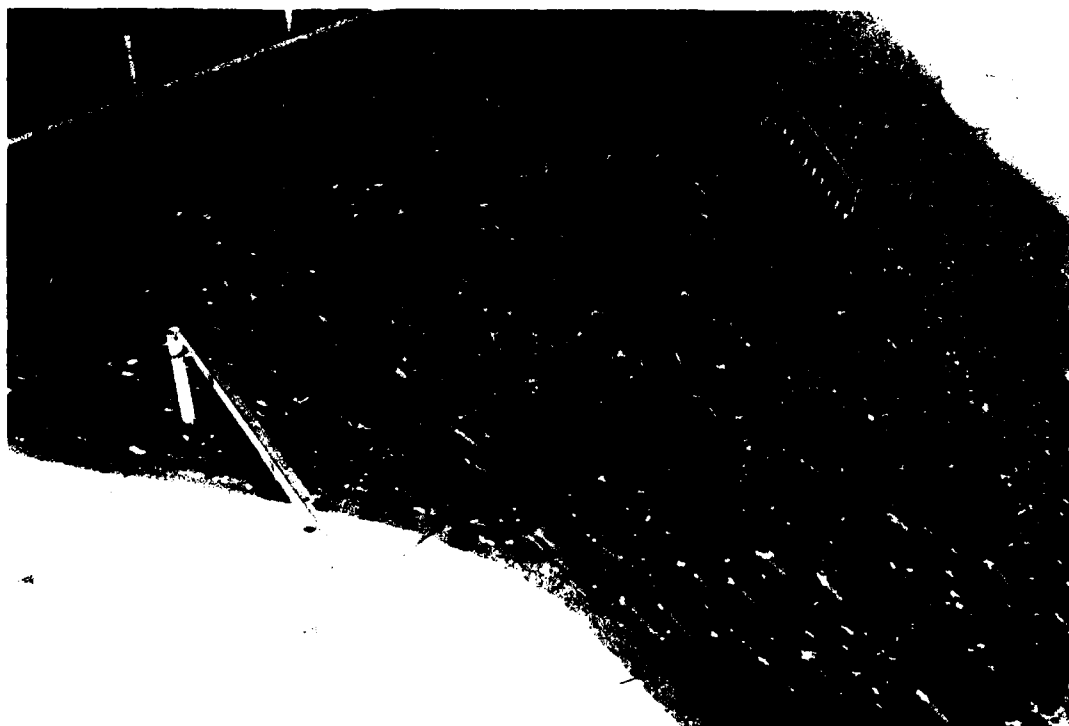
Photo 12. Ice flow during filling operation



Photo 13. Dry bed of the three intakes

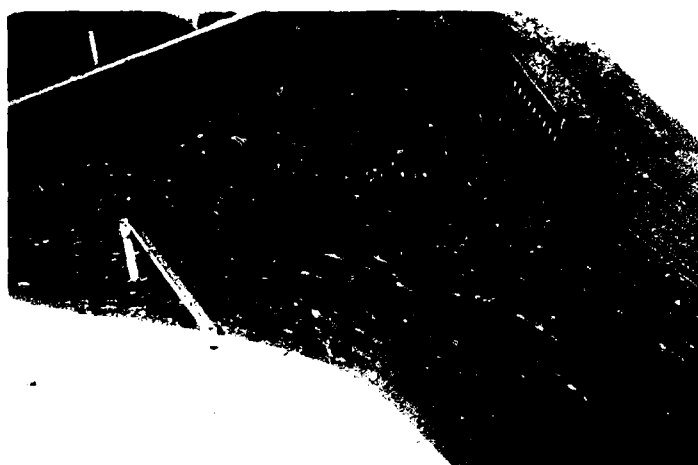


a. Before filling started



b. 2.0 min after filling started

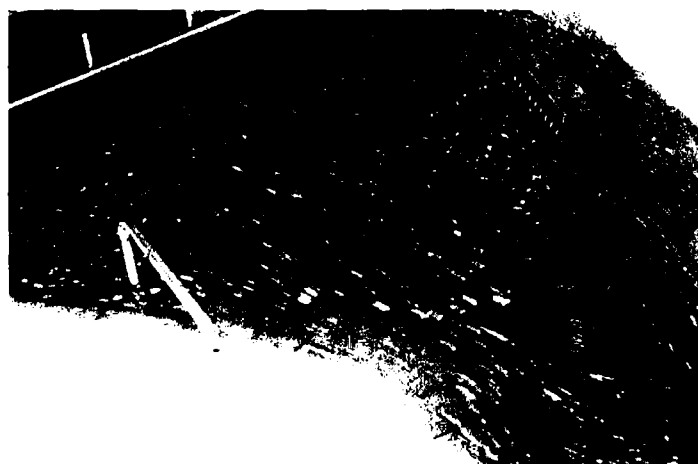
Photo 14. Surface currents during filling operation; original design, time exposure 10 sec, upper pool el 538.0 (Continued)



c. 4.0 min after filling started



d. 6.0 min after filling started



e. 8.0 min after filling started

Photo 14. (Concluded)



Photo 15. Type 1 design approach wall

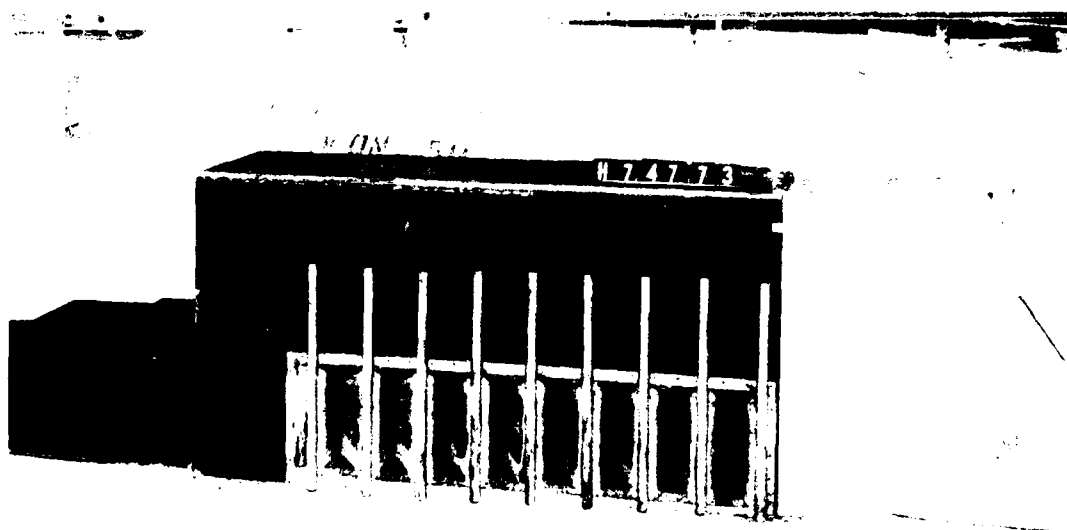


Photo 16. Type 11 (recommended) design approach wall

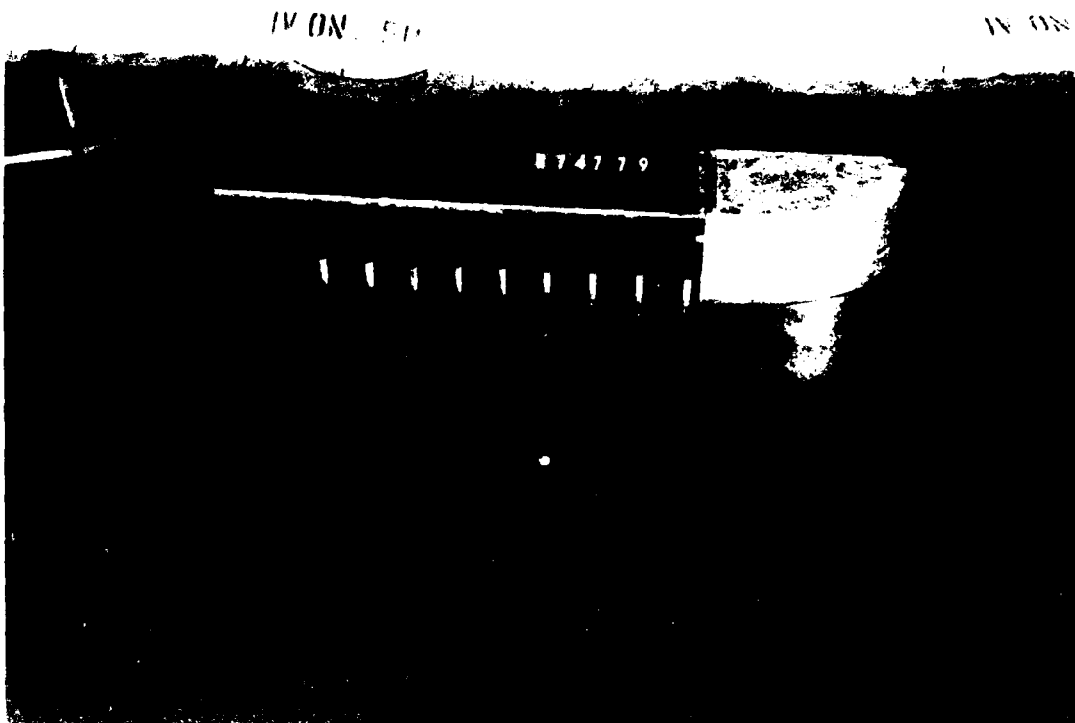
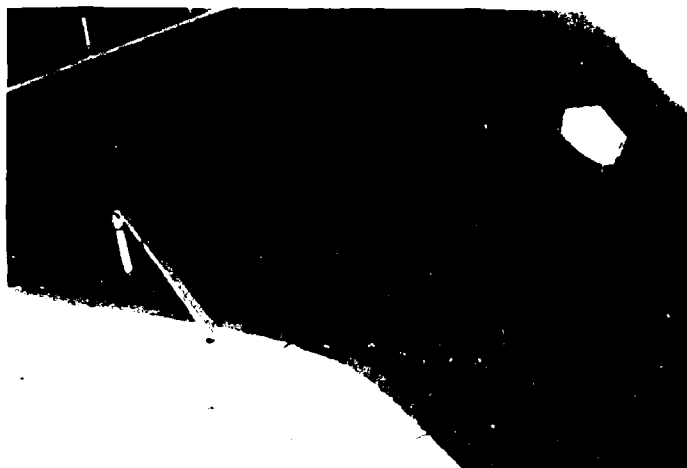
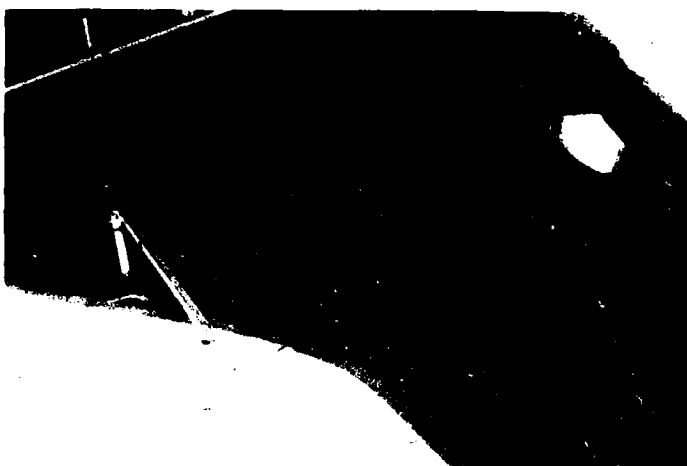


Photo 17. Type 11 (recommended) design approach wall flow shot



a. Before filling started

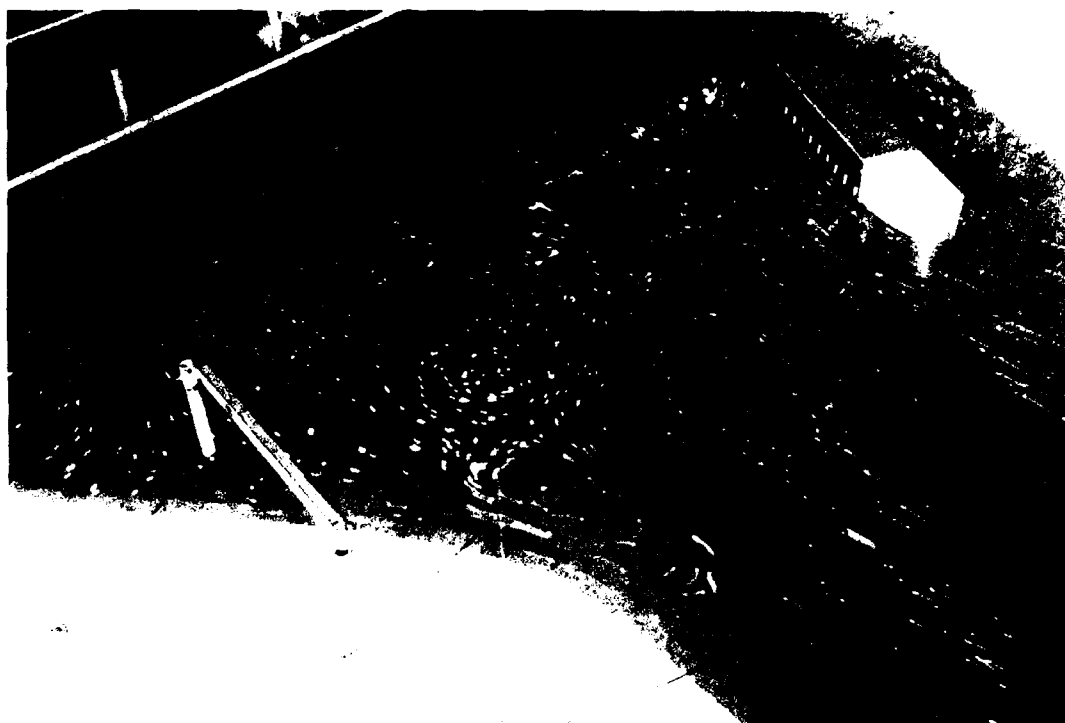


b. 2.0 min after filling started

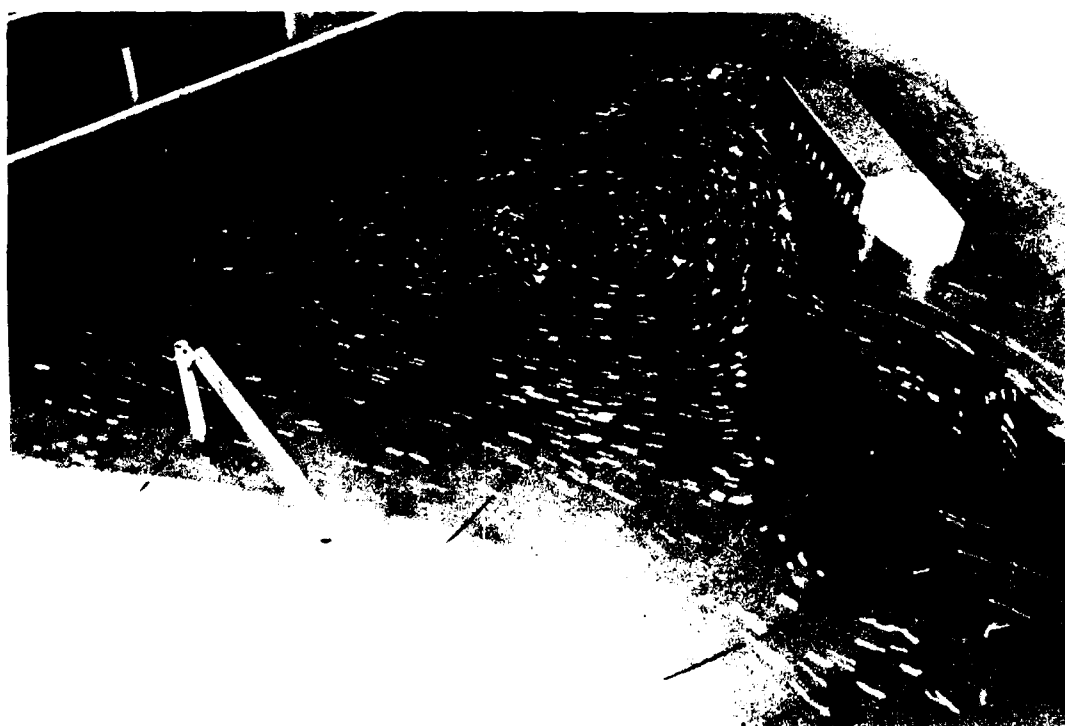


c. 4.0 min after filling started

Photo 18. Surface currents during a filling operation; type 11 (recommended) design approach wall, upper pool el 538.0 (Continued)

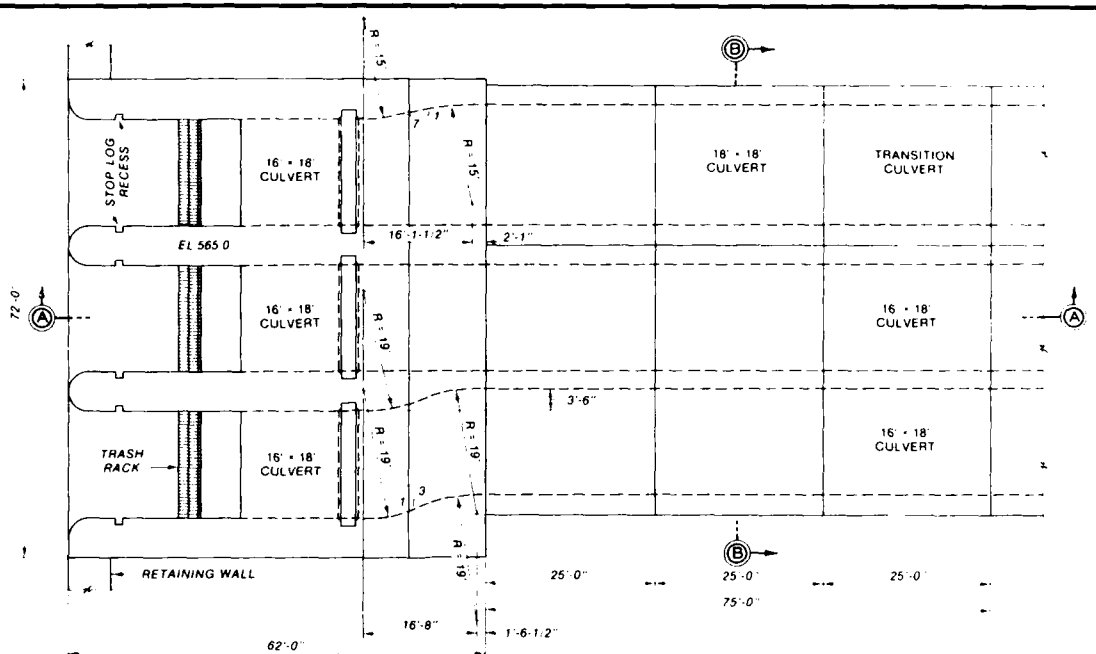


d. 6.0 min after filling started

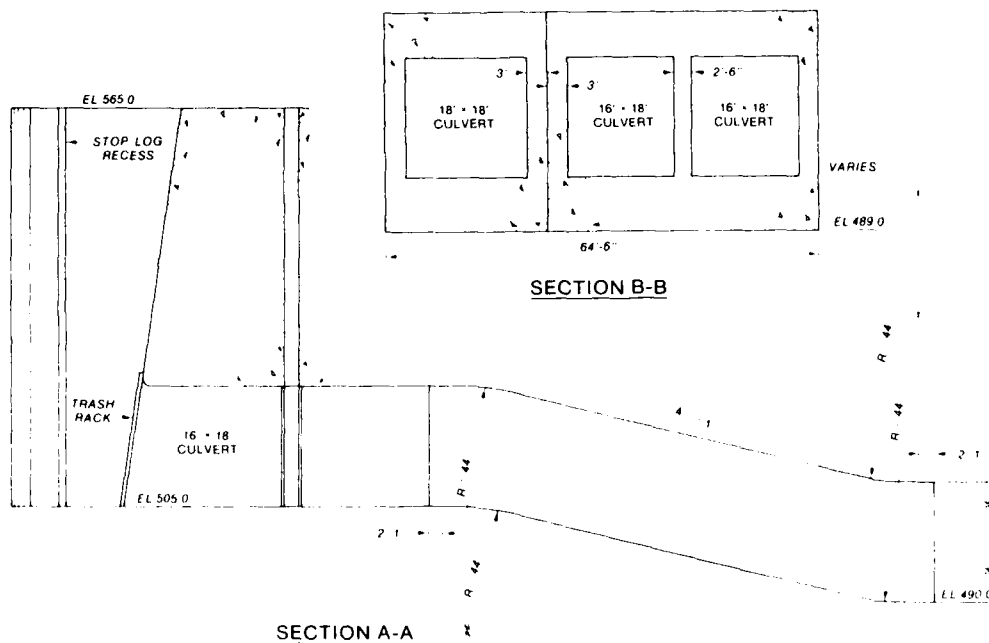


e. 8.0 min after filling started

Photo 18. (Concluded)



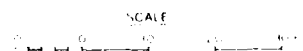
PLAN

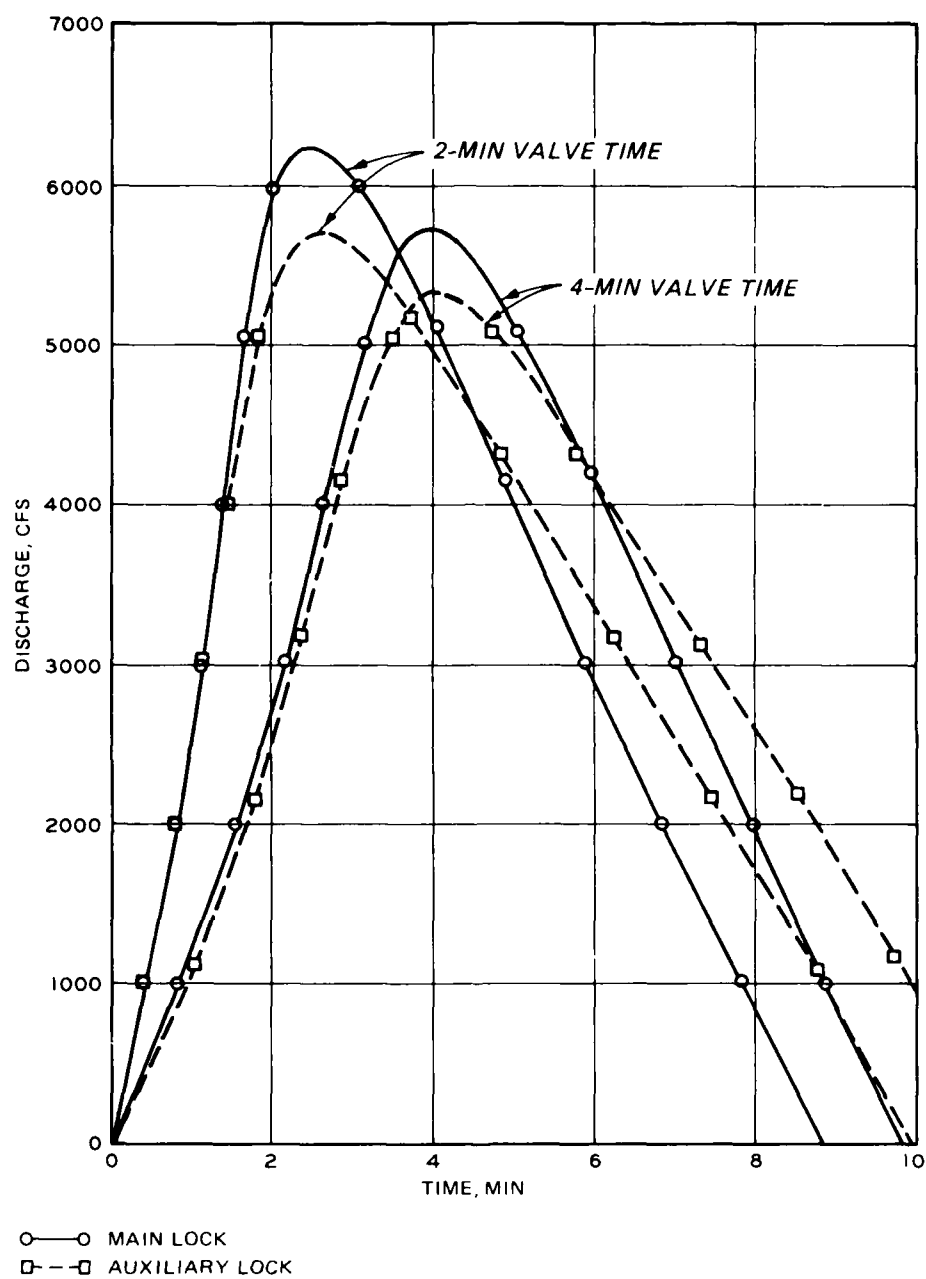


SECTION A-A

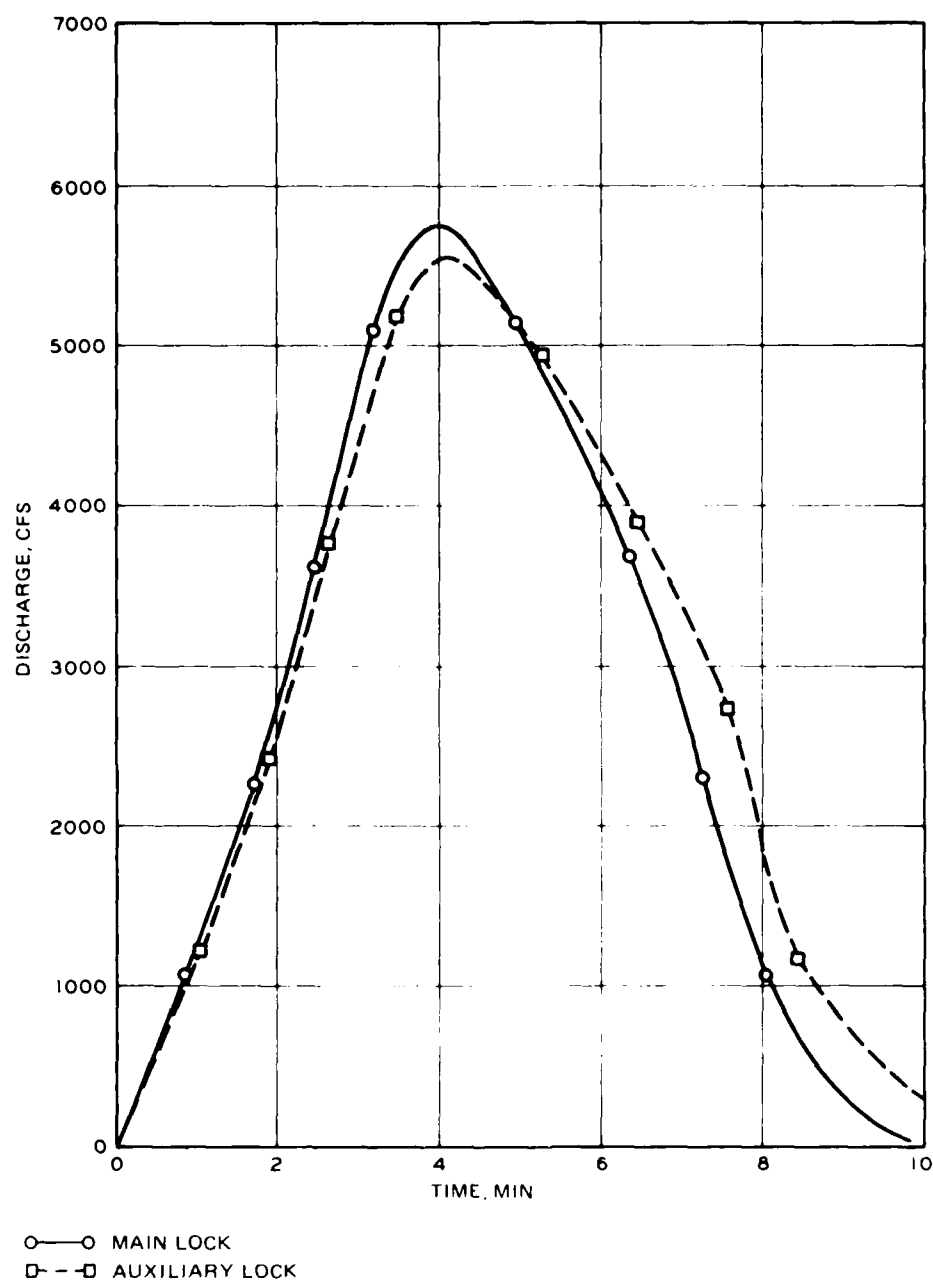
SECTION B-B

INTAKE STRUCTURE
ALTERNATIVE FILLING SCHEME
TYPE 1 DESIGN INTAKE





ALTERNATIVE I FILLING SCHEME
FILLING HYDROGRAPHS

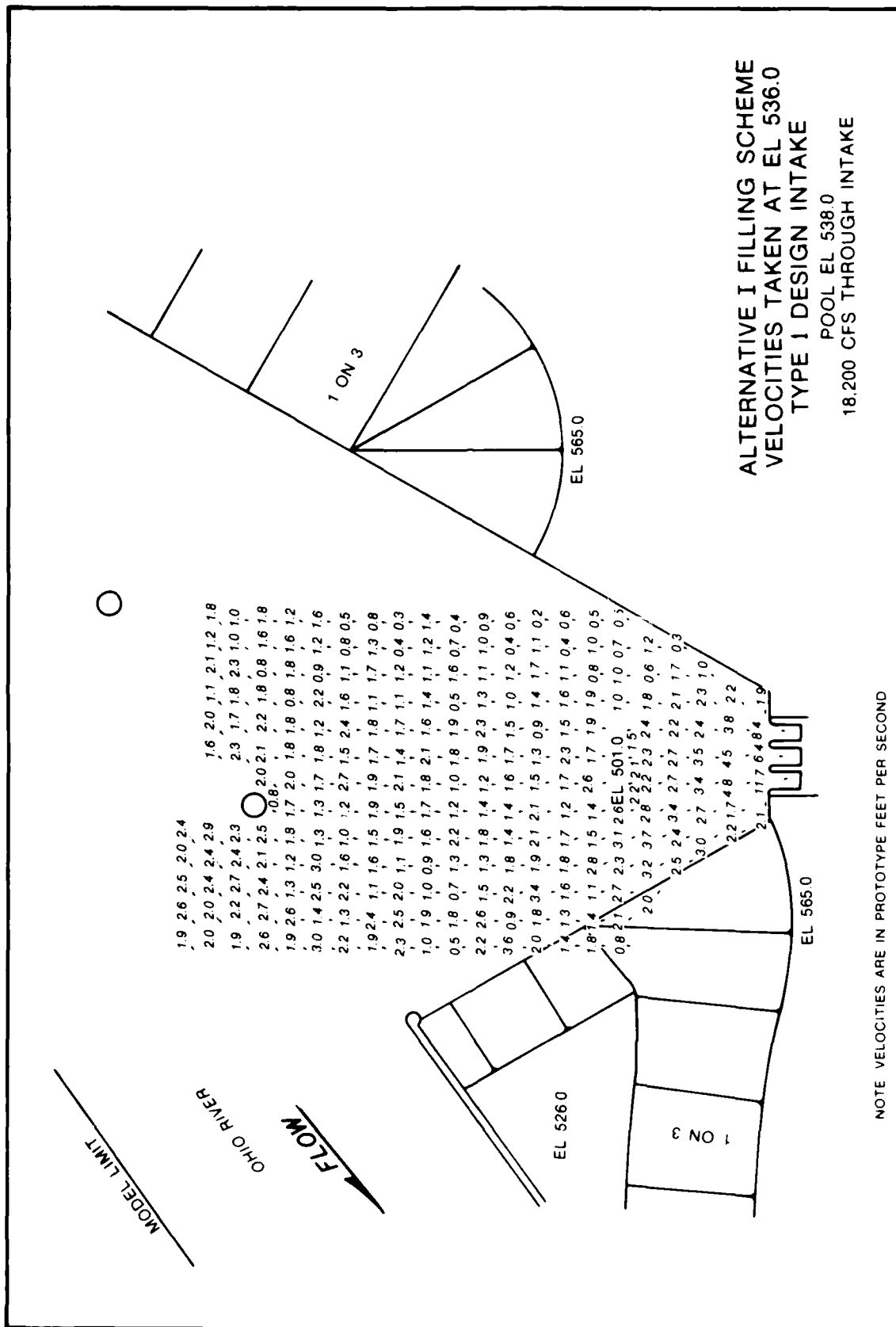


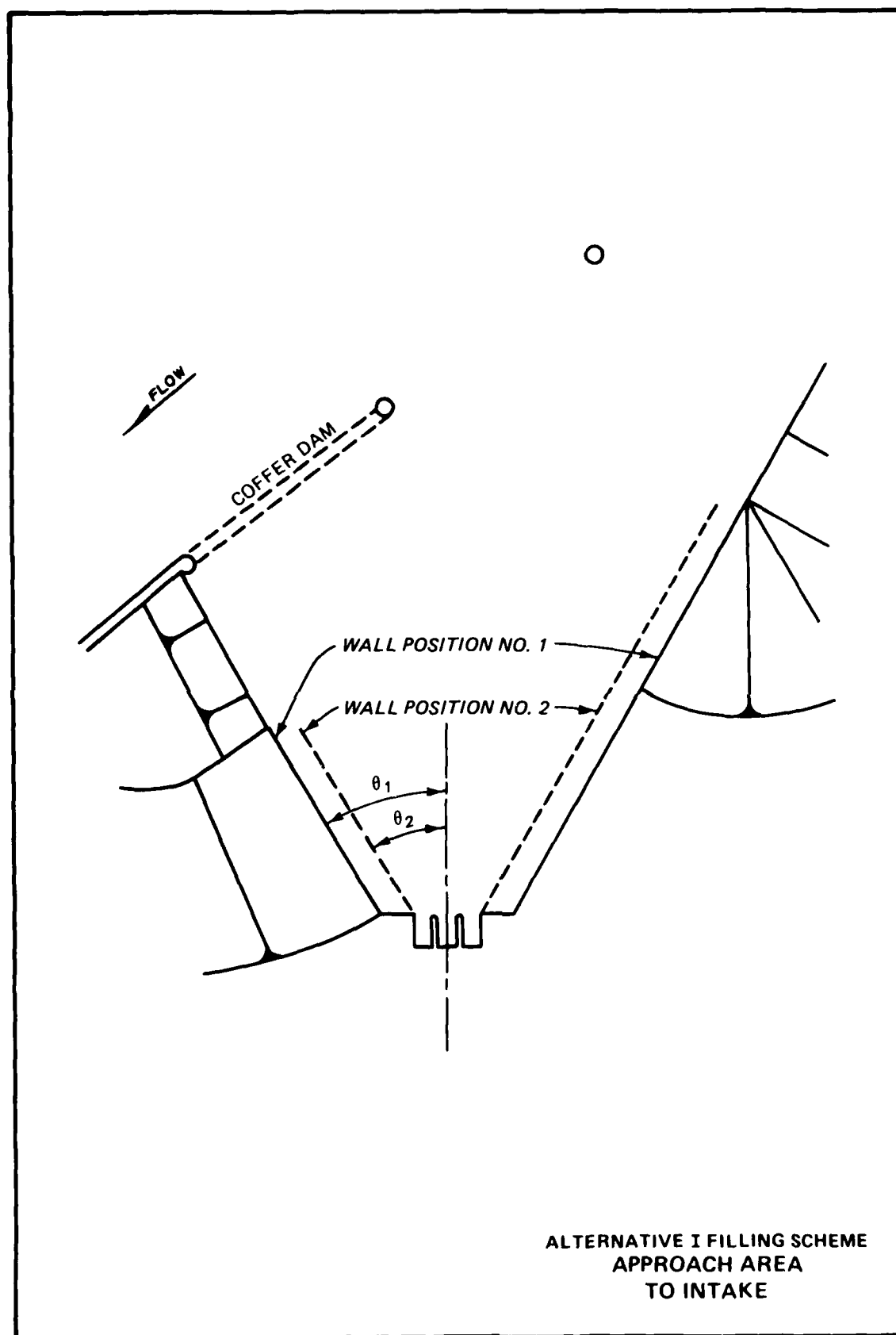
ALTERNATIVE II FILLING SCHEME
FILLING HYDROGRAPH
4-MIN VALVE TIME



ALTERNATIVE I FILLING SCHEME
VELOCITIES TAKEN AT EL 508.0
TYPE I DESIGN INTAKE
POOL EL 538.0
18,200 CFS THROUGH INTAKE







STOP LOG
RECESS

BULKHEAD SLOT

FLOW

TRASHRACK

16' X 18'
CULVERT

TYPE 1 DESIGN INTAKE

GRIDDED BAR RACKS
PLACED IN STOP
LOG RECESS

BULKHEAD SLOT

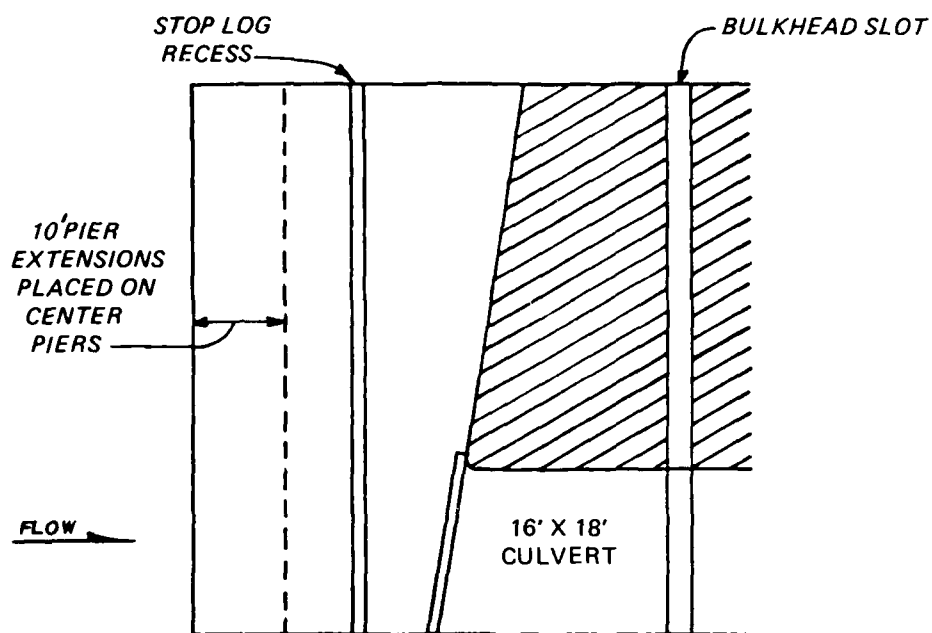
FLOW

TRASHRACK

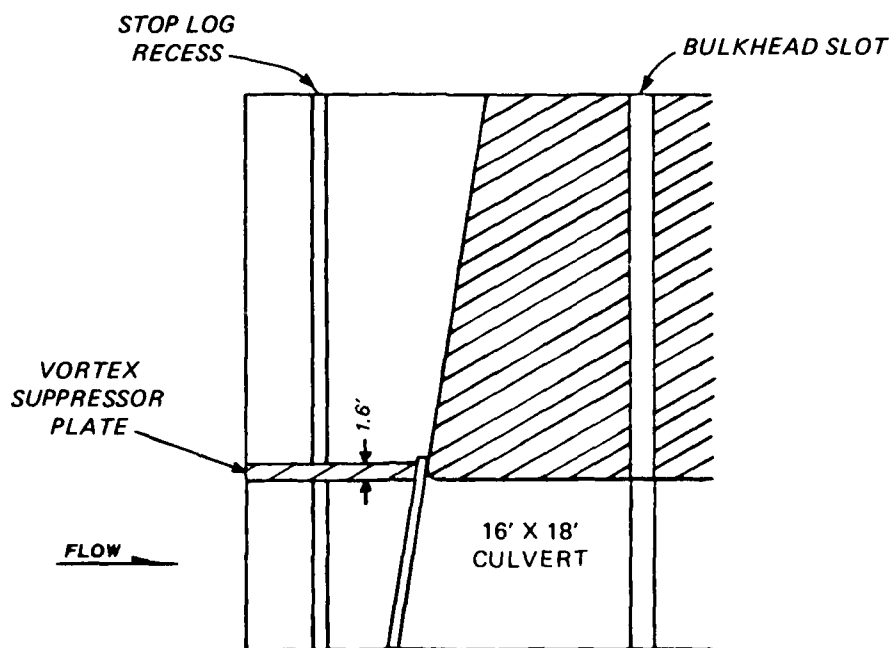
16' X 18'
CULVERT

TYPE 2 DESIGN INTAKE

ALTERNATIVE I FILLING SCHEME
INTAKE DESIGNS
TYPES 1 AND 2

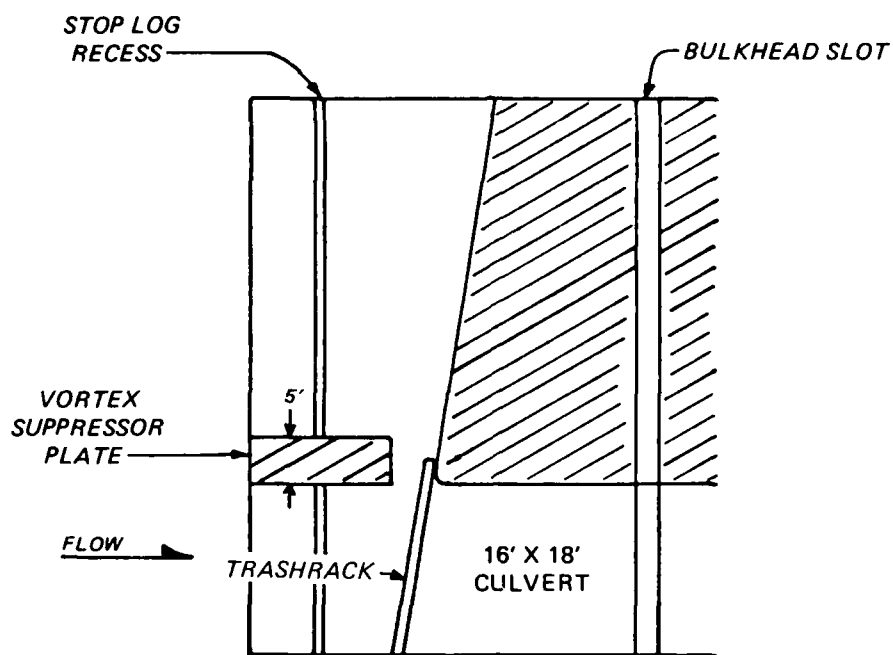


TYPE 3 DESIGN INTAKE

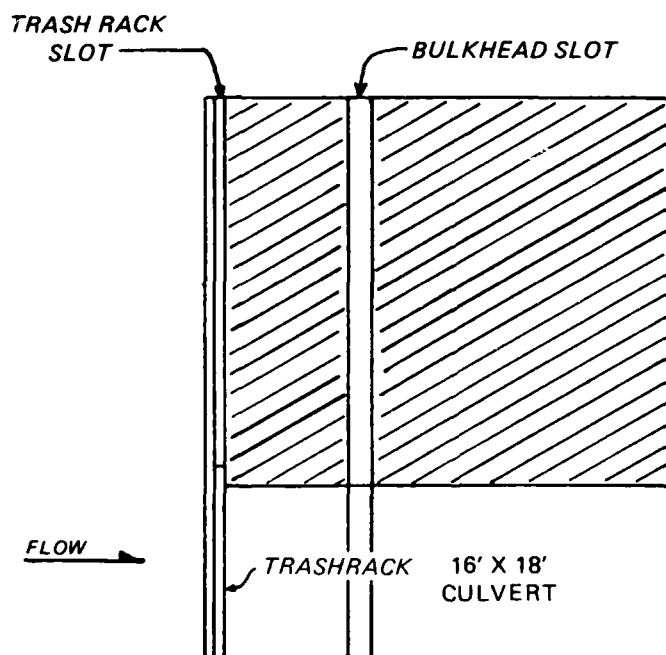


TYPE 4 DESIGN INTAKE

ALTERNATIVE I FILLING SCHEME
INTAKE DESIGNS
TYPES 3 AND 4

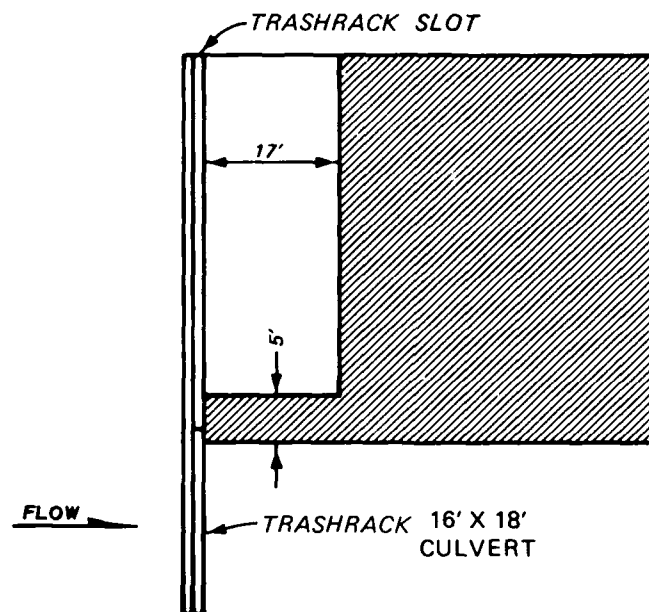


TYPE 6 DESIGN INTAKE

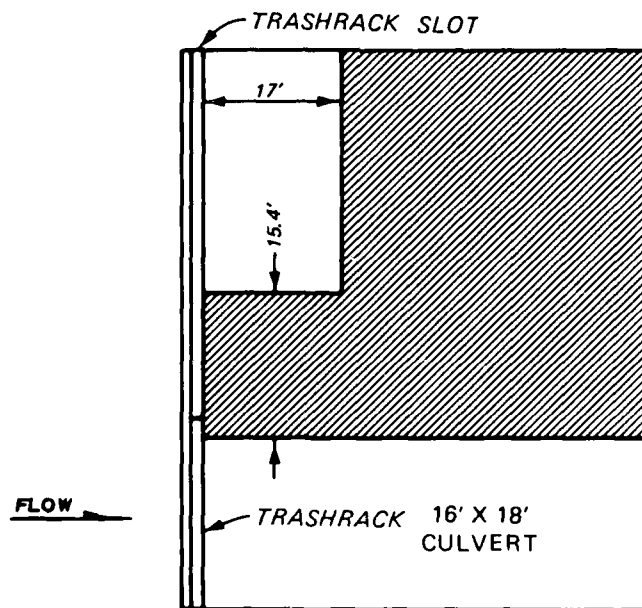


TYPE 5 DESIGN INTAKE

ALTERNATIVE I FILLING SCHEME
INTAKE DESIGNS
TYPES 5 AND 6

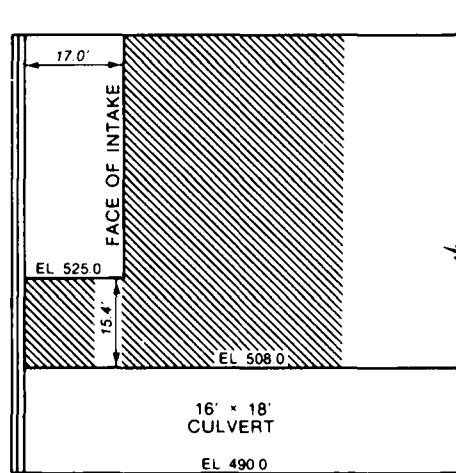


TYPE 7 DESIGN INTAKE

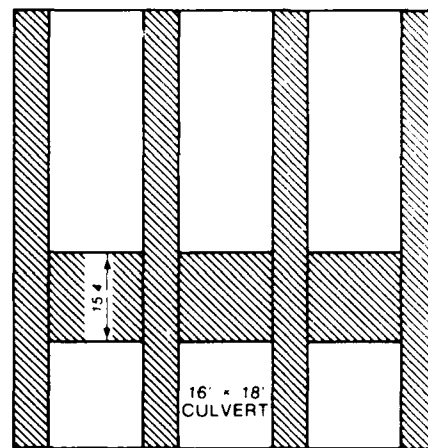


TYPE 8 DESIGN INTAKE

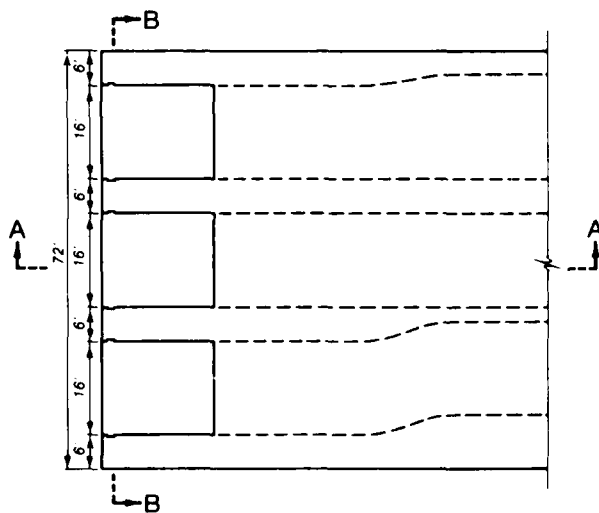
ALTERNATIVE I FILLING SCHEME
INTAKE DESIGNS
TYPES 7 AND 8



SECTION A-A

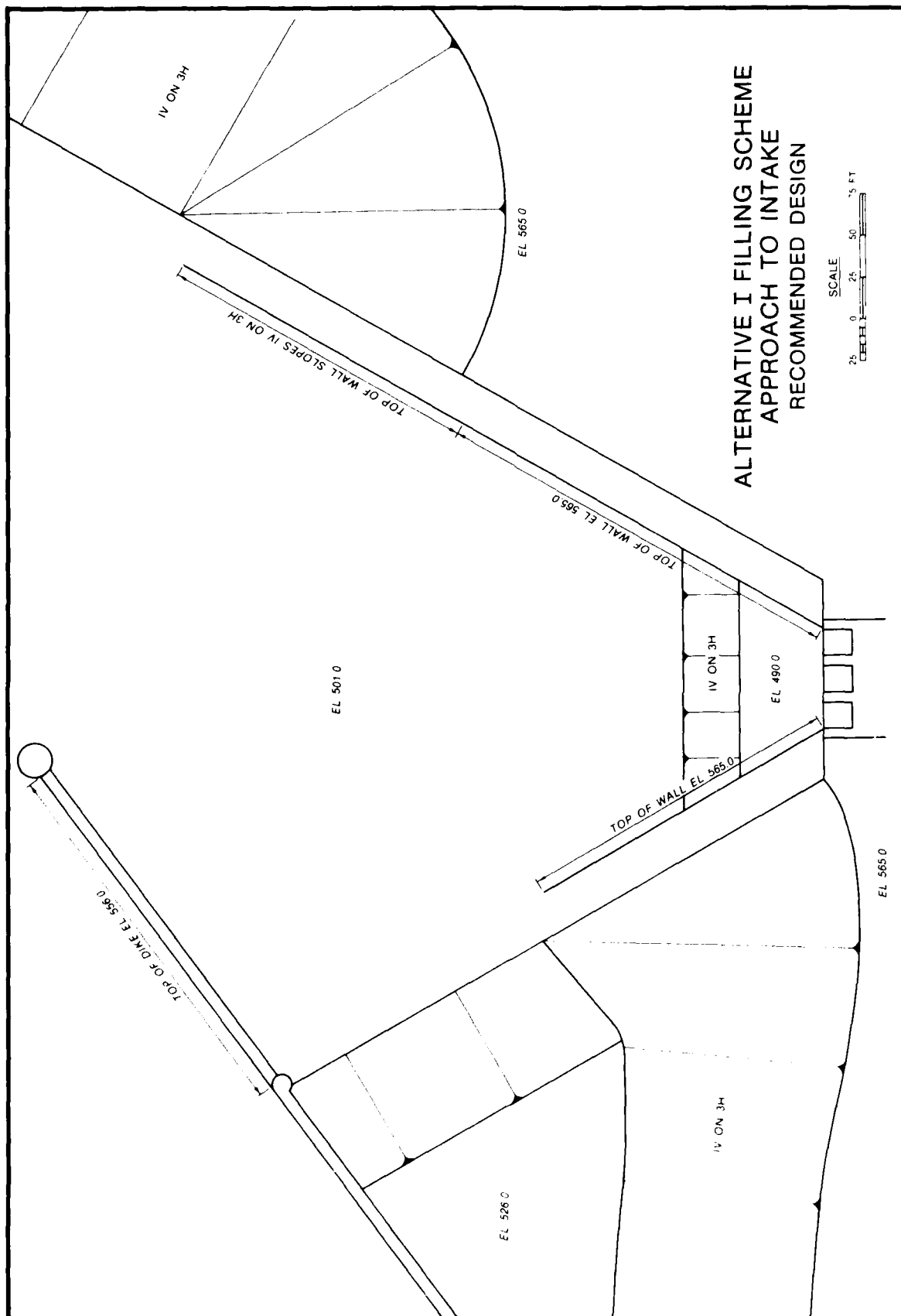


SECTION B-B



PLAN

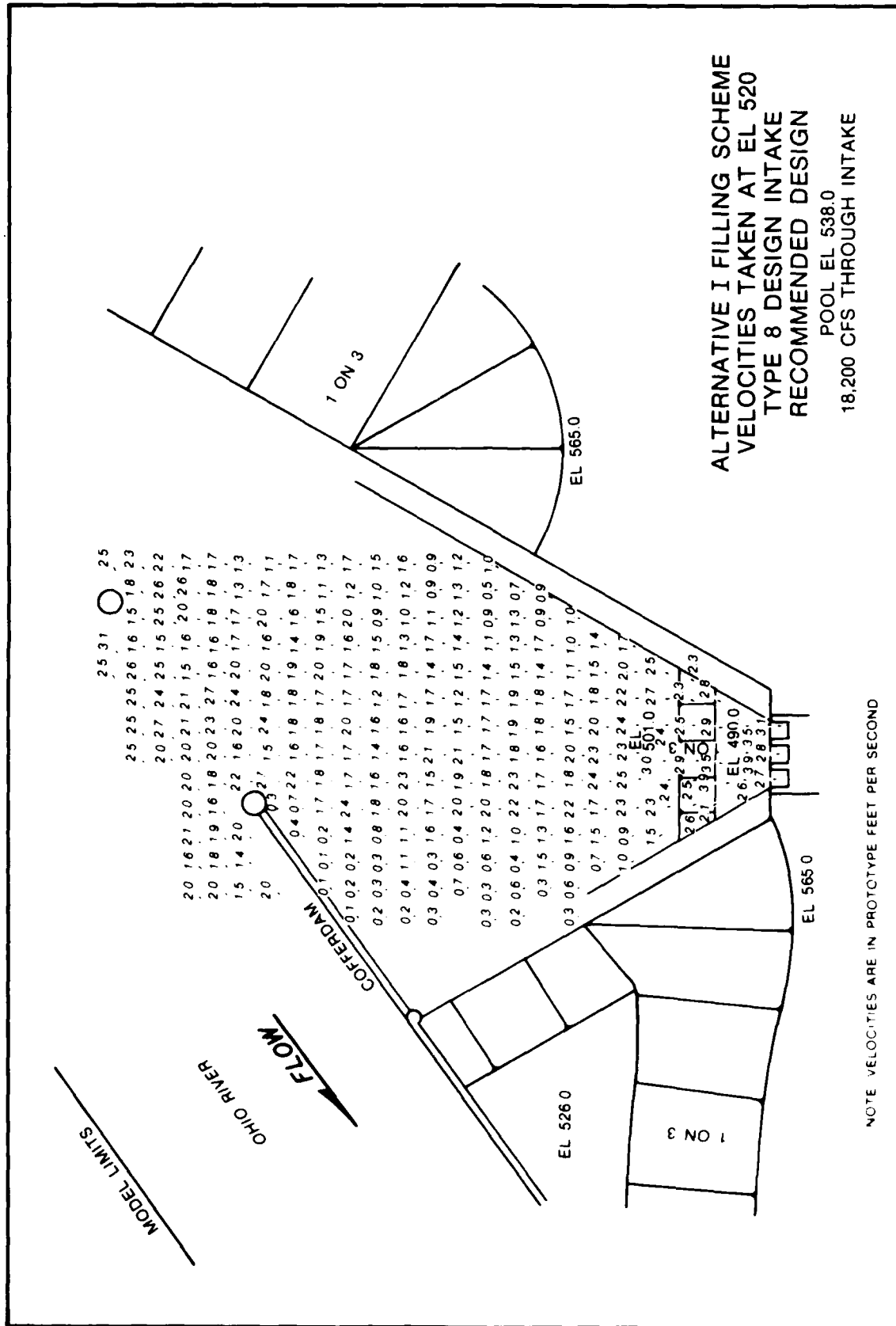
ALTERNATIVE I FILLING SCHEME
INTAKE STRUCTURE
RECOMMENDED DESIGN



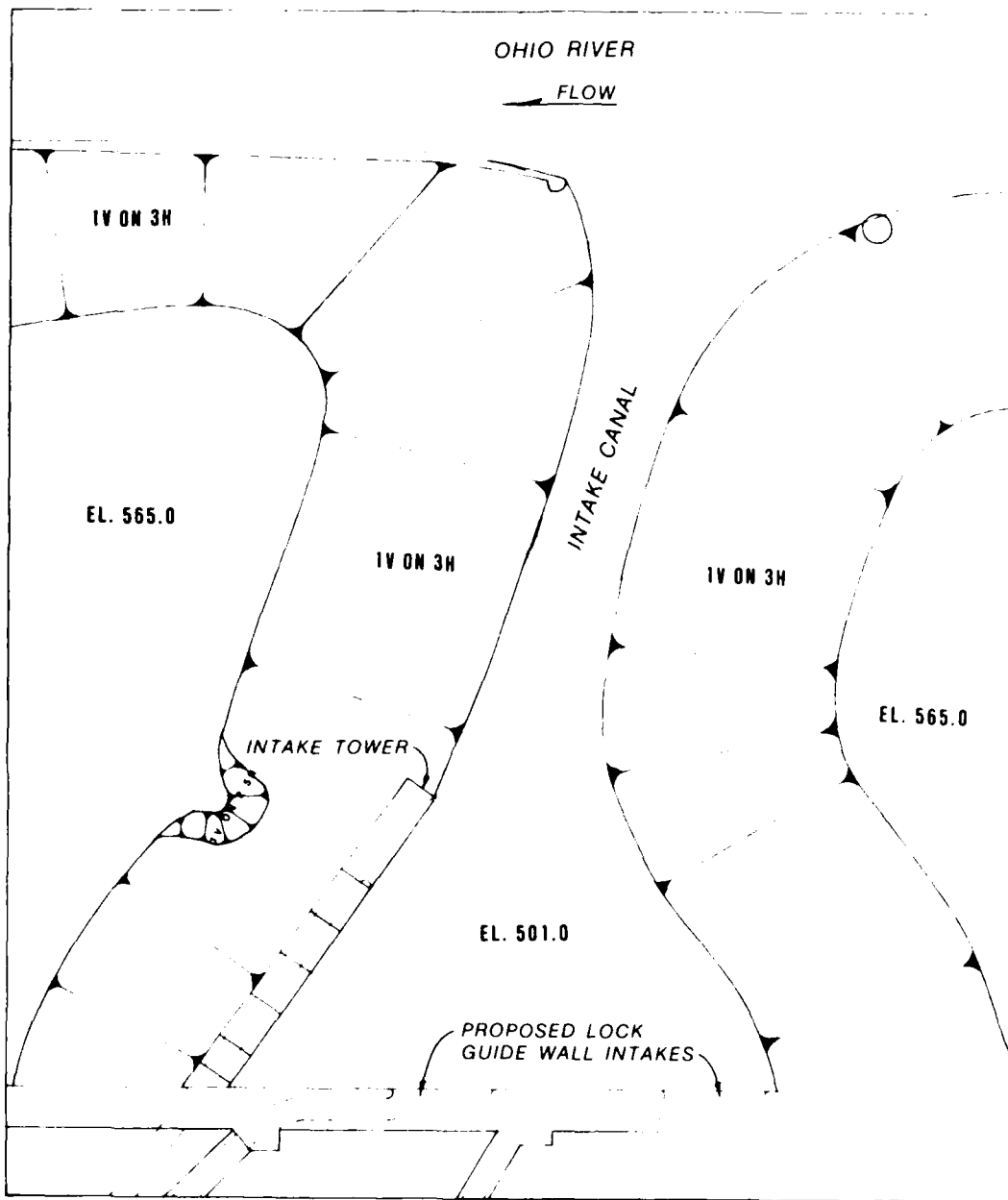
ALTERNATIVE I FILLING SCHEME
 APPROACH TO INTAKE
 RECOMMENDED DESIGN



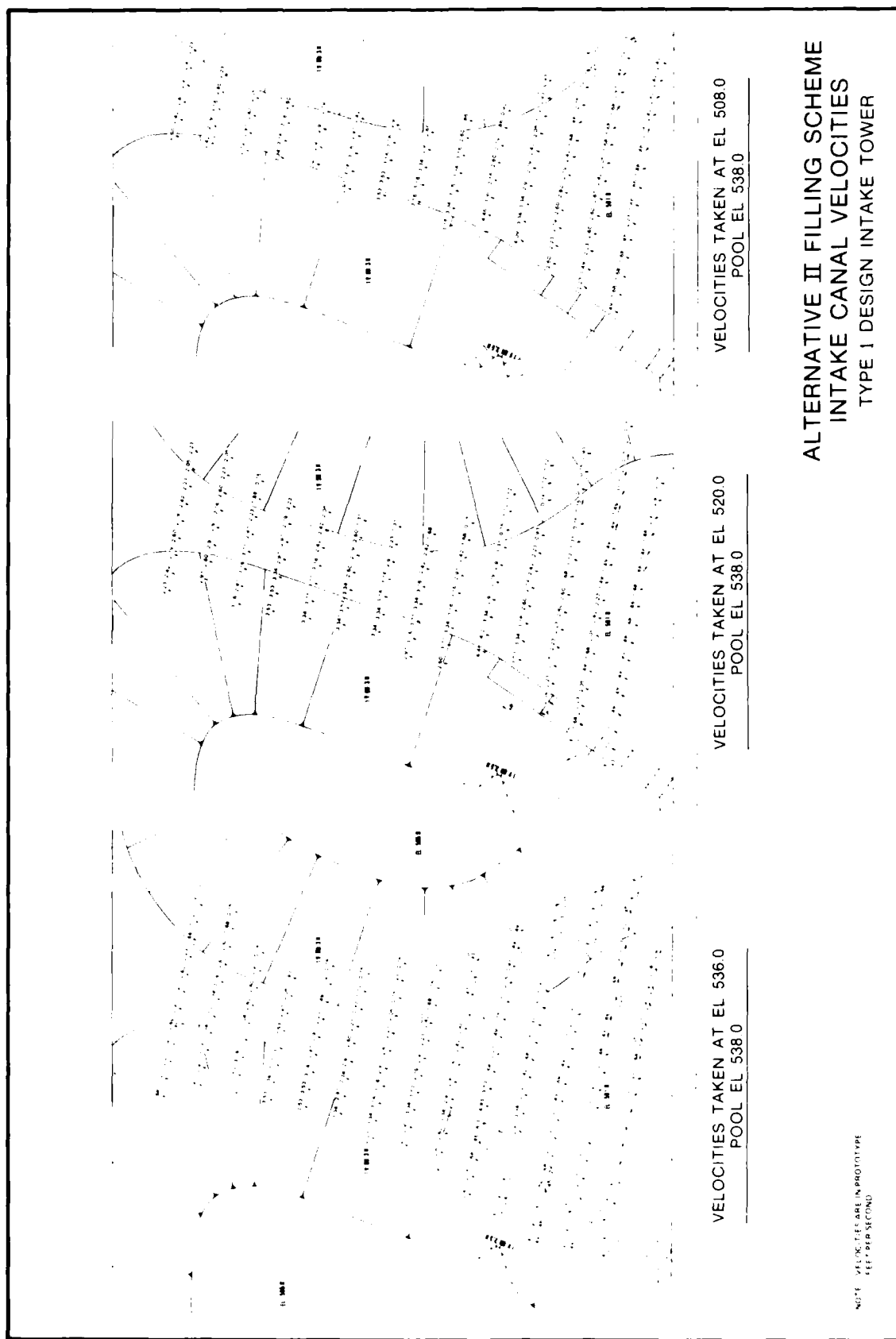
ALTERNATIVE I FILLING SCHEME
VELOCITIES TAKEN AT EL 508
TYPE 8 DESIGN INTAKE
RECOMMENDED DESIGN
POOL EL 538.0
18,200 CFS THROUGH INTAKE

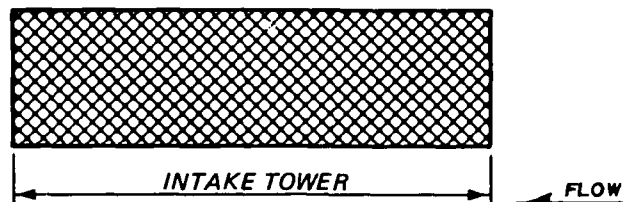




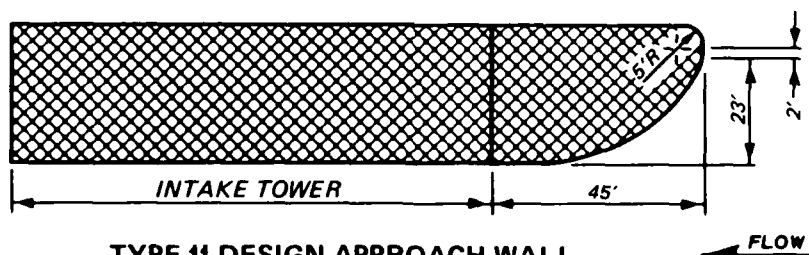


ALTERNATIVE II FILLING SCHEME
INTAKE CANAL
TYPE 1 DESIGN APPROACH WALL



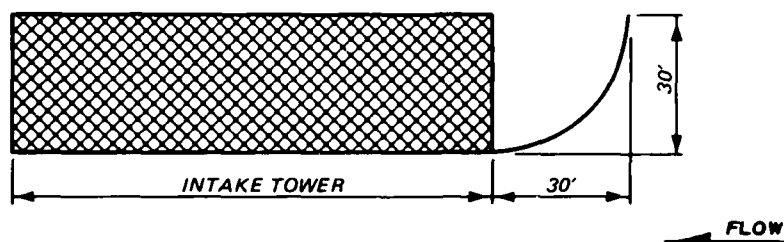


**TYPE 1 DESIGN APPROACH WALL
(ORIGINAL DESIGN)**

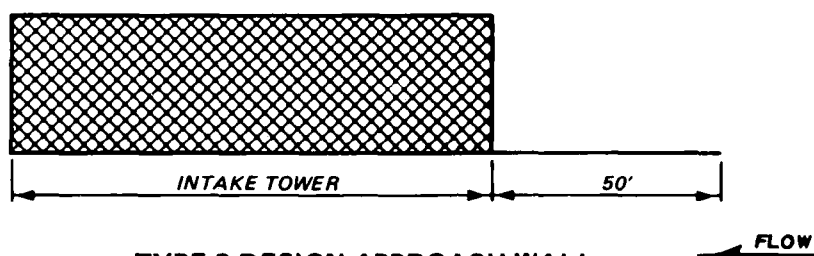


**TYPE 11 DESIGN APPROACH WALL
(RECOMMENDED DESIGN)**

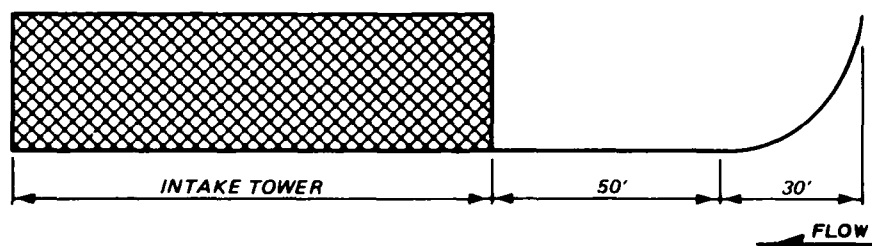
**ALTERNATIVE II FILLING SCHEME
APPROACH WALL DESIGNS
TYPES 1 AND 11
PLAN VIEW**



TYPE 2 DESIGN APPROACH WALL

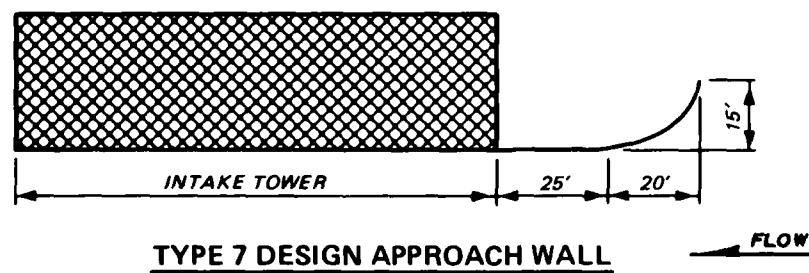
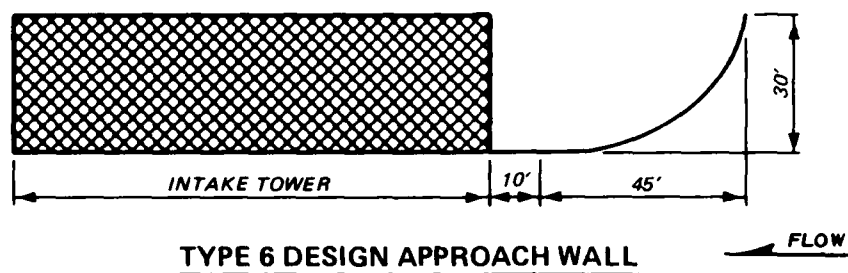
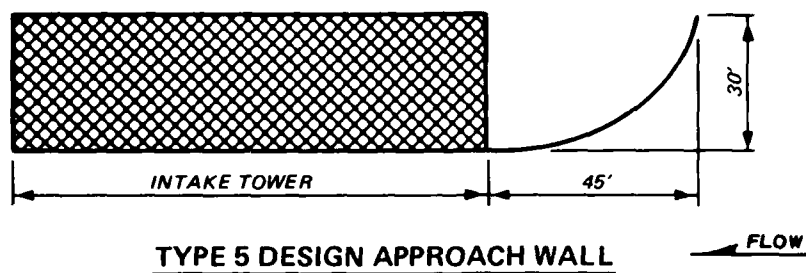


TYPE 3 DESIGN APPROACH WALL

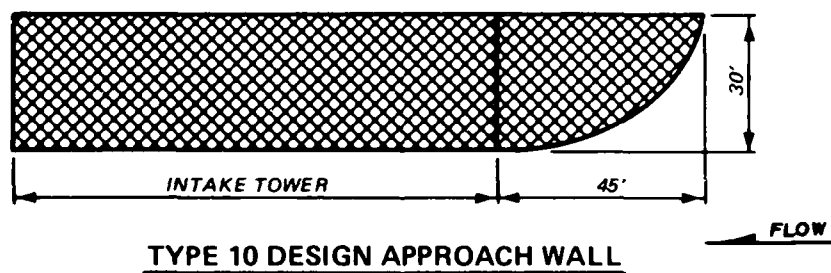
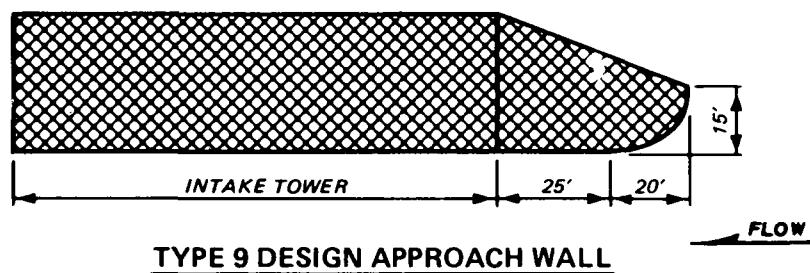
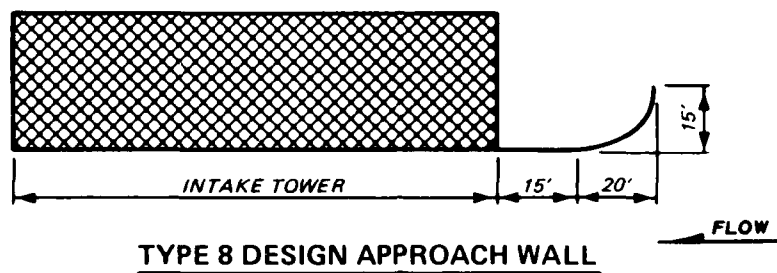


TYPE 4 DESIGN APPROACH WALL

ALTERNATIVE II FILLING SCHEME
 APPROACH WALL DESIGNS
 TYPES 2, 3, AND 4
 PLAN VIEW



ALTERNATIVE II FILLING SCHEME
 APPROACH WALL DESIGNS
 TYPES 5, 6, AND 7
 PLAN VIEW



ALTERNATIVE II FILLING SCHEME
APPROACH WALL DESIGNS
TYPES 8, 9, AND 10
PLAN VIEW



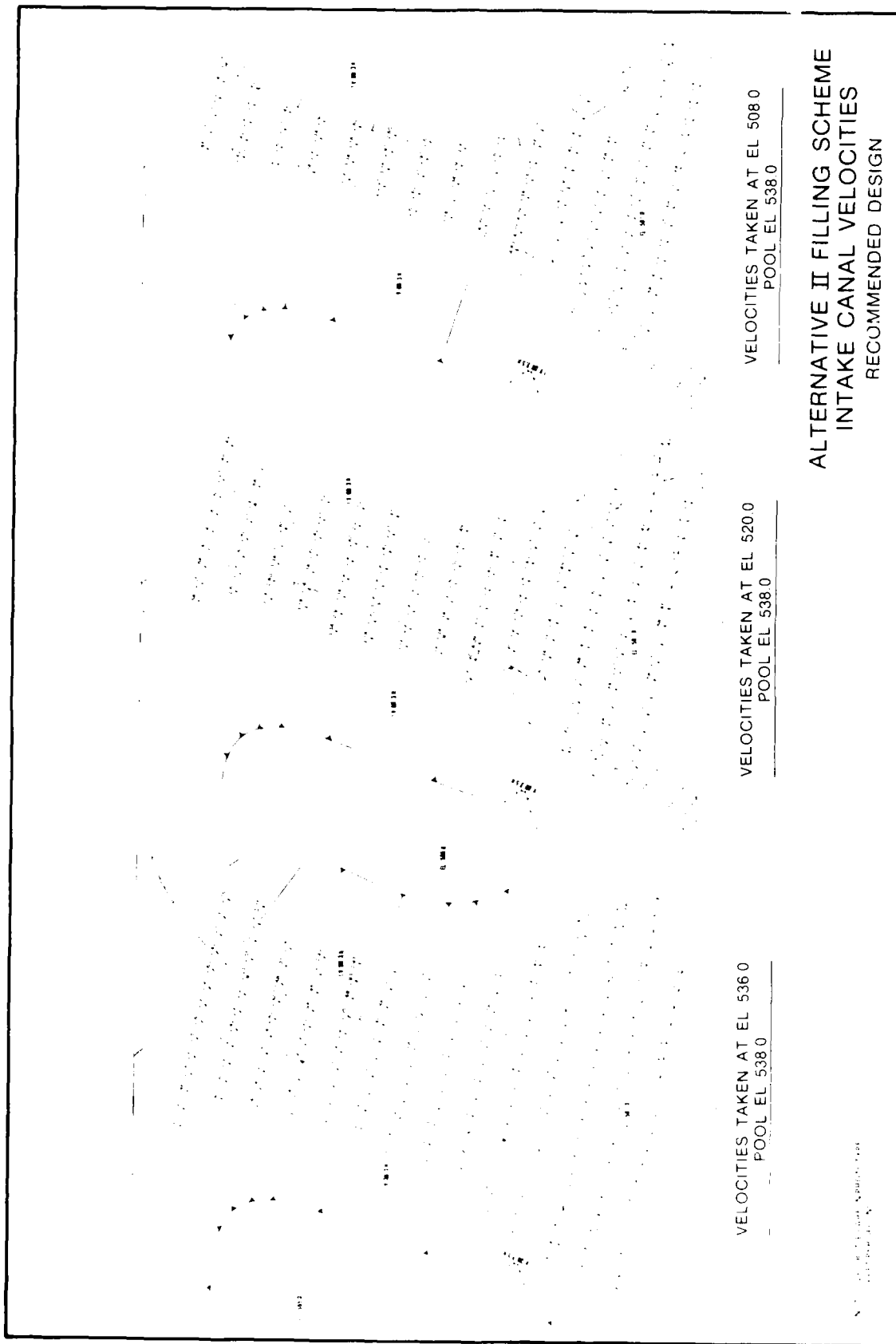


PLATE 24

END

3-88

DTIC